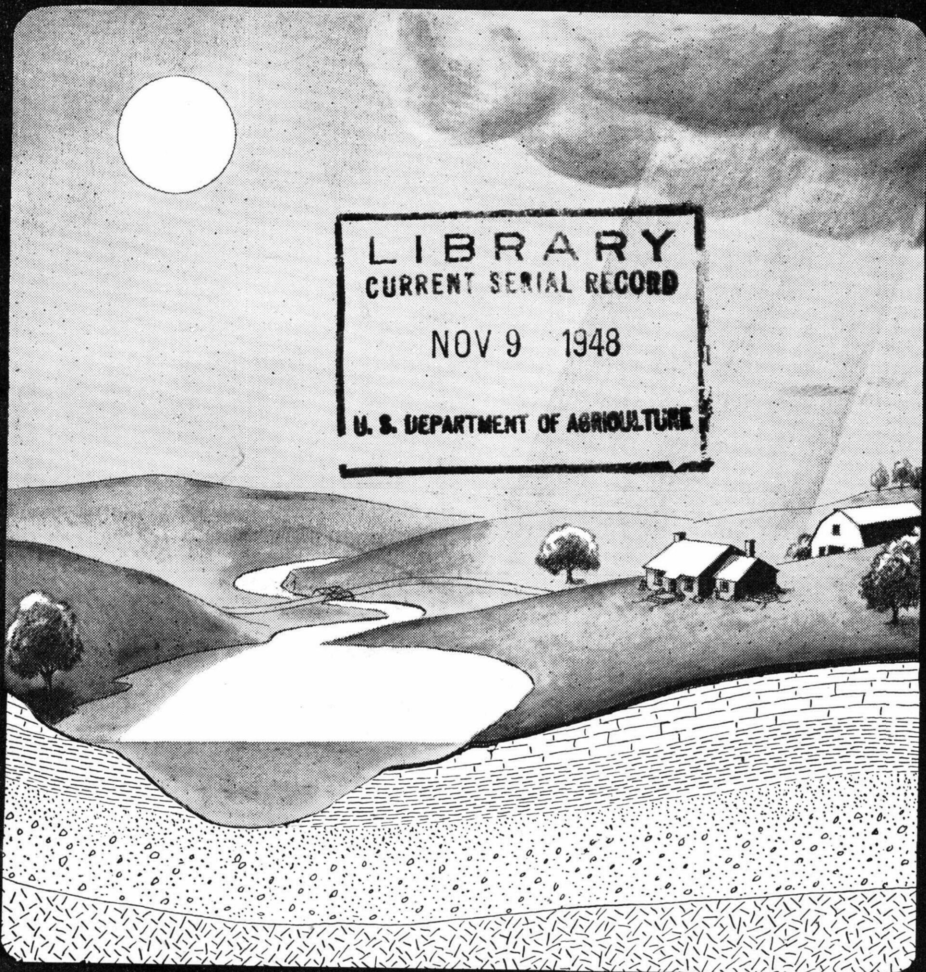
Safe Water FOR THE FARM



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U. S. DEPARTMENT OF AGRICULTURE

EVERY farmer needs an abundant and dependable supply of water, both for the farm family and the livestock and possibly for use in irrigation and fire control. The importance of a well-planned water system cannot be overestimated. Because a water system is a relatively permanent installation, the farmer should give it a great deal of study before spending money for labor and equipment.

To supply information regarding the sanitary and engineering principles required in providing safe fresh water for rural homes and farms is the purpose of this bulletin. It supersedes Farmers' Bulletin 1448, Farmstead Water Supply.

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SAFE WATER FOR THE FARM

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Contents [1]

	Page
Importance of a safe water supply	2
Quality of water	2
Characteristics of safe water	2
Safeguarding the supply	3
Protecting springs and wells	5
Cleaning wells	6
Disinfecting wells	7
Analysis of water	7
Care and treatment of water	8
Disinfecting water	8
Softening	9
Removing iron	10
Filtering	11
Quantity of water required	12
Domestic and livestock requirements	12
Fire-protection requirements	13
Irrigation requirements	13
Sources of water	13
Ground water	14
Springs	14
Wells	14
Drilled wells	14
Jetted wells	16
Driven wells	17
Bored wells	18
Dug wells	19
Reconstruction of dug wells	21
Source of water—Continued	
Ground Water—Continued	
Location of wells	22
Abandoning wells	23
Surface water	23
Pumps and pumping	24
Types of pumps	25
Plunger pumps	25
Turbine pumps	26
Centrifugal pumps	27
Rotary pumps	28
Ejector pumps	28
Hand pumps	31
Hydraulic rams	31
Siphons	32
Selection of pumps	33
Installation of pumps	35
Priming	35
Foot valves	36
Frost protection	36
Power for pumping	36
Electric power	37
Windmills	38
Internal-combustion engines	39
Water storage	39
Elevated tanks	40
Hydropneumatic tanks	42
Cisterns	43
Ponds	45
Pipes and pipe fittings	46

[1] The order in which the various topics are discussed conforms with that of Rural Water-Supply Sanitation, Recommendations of the Joint Committee on Rural Sanitation, published by the Federal Security Agency, U. S. Public Health Service, Public Health Reports, Sup. 185, 56 pp., illus. 1945.

IMPORTANCE OF A SAFE WATER SUPPLY

WATER is one of Nature's most valuable and most common gifts to man. It is present in the atmosphere as high as he flies and in the earth as deep as he digs, and it covers approximately three-fourths of the earth's surface.

Water is essential to plants and animals and makes up high percentages of their structure. Liquids composed largely of water carry nourishment to all parts of these plants and animals and also remove impurities and waste materials. Only water that is safe should be taken into the body.

In nature, water is seldom free from impurities. The pure vapor in the atmosphere may, upon condensing and falling through the dust-laden air, collect air-borne bacteria. In percolating through the earth water loses by filtration most, if not all, of the air-borne contamination, but usually it picks up soluble salts or gases or both. Fortunately, most of these salts and gases are harmless except in abnormally large quantities, but occasionally some are harmful or even dangerous, such as methane gas found in ground waters in some parts of the Central States. Calcium and magnesium in the form of sulfates or carbonates are common, as also is iron.

Specific directions for locating water in every community, or for treating it when found, are beyond the scope of this bulletin. Earth strata (rock layers) vary from one community to another, as also do the minerals that may be dissolved by water. Some of the recommendations presented here [2] may require modification to adapt them to local conditions. County health officers, county agricultural agents, and other local authorities, and State geologists, health departments, and colleges or universities should be consulted on problems of a purely local nature.

QUALITY OF WATER

CHARACTERISTICS OF SAFE WATER

Pure water is clear, colorless, odorless, and tasteless. The taste in certain waters we like is due to the accumulation of dissolved mineral salts or other ingredients. If the material picked up is harmful, the water is said to be polluted. The addition of mineral salts changes its character. Water containing comparatively large quantities of calcium and magnesium salts is called hard, as common soaps do not form suds readily in it. Rain water, which contains very little mineral matter, is called soft, for in it soap ordinarily forms suds readily.

Water for domestic use should be pure, soft, cool, and free from excess acidity or alkalinity. Water may be odorless, colorless, and

[2] Appreciation is expressed to members of the Department of Agriculture Environmental Sanitary Engineering Committee; to specialists of the Bureau of Plant Industry, Soils, and Agricultural Engineering; and to Clifford Betts, of the Forest Service, for helpful suggestions; and to the following manufacturers for furnishing photographs: Clayton Mark & Co., figs. 8, *A* and *B*, and 20; Edward E. Johnson, Inc., fig. 8, *C*; F. E. Myers & Bros. Co., figs. 13 and 17; Goulds Pumps, Inc., fig. 14; and the Deming Co., fig. 15.

soft and at the same time impure. A glass of water possessing all the desirable qualities except purity may contain millions of dangerous organisms. Disease-producing bacteria cannot be seen with the naked eye, and thousands may lurk in a drop of water or in a particle of waste matter no larger than a pinhead. Specific germs or parasites in contaminated water may cause typhoid fever, dysentery, diarrhea, or intestinal worms, the more common of which are hookworm, roundworm, whipworm, eelworm, tapeworm, and seatworm. The fact that water may be dangerous is seldom realized until after a case of sickness or death. A safe water supply should be the farmer's first consideration when planning a new well or buying a farm.

Contaminated water may contain also the causative agents of ailments common to livestock, such as tuberculosis, hog cholera, anthrax, glanders, and stomach and intestinal worms. Disease germs are carried

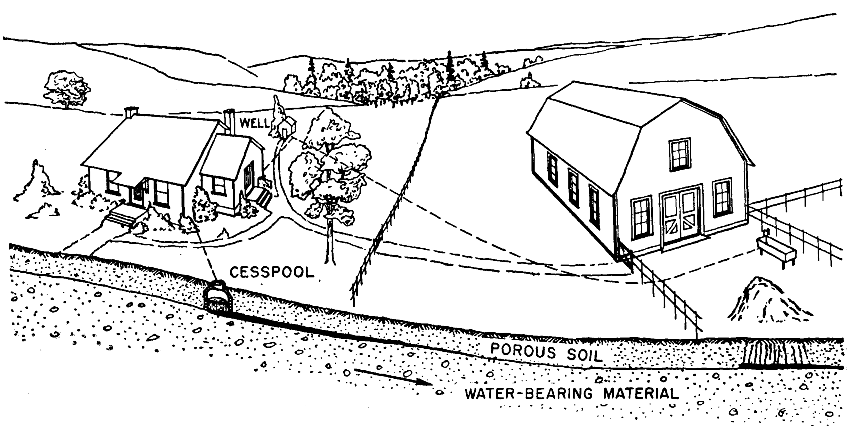

Figure 1.—Farmstead, showing how to avoid some common sources of contamination in locating the well. Arrow indicates direction of travel of ground water.

in many ways and are unsuspectingly received into the body. A high percentage of farm water supplies is sufficiently polluted to be unsafe. Streams, ponds, irrigation ditches, and other surface supplies are sure to receive pollution, either directly or from surface wash. Wells and springs are polluted through open or loose covers and by foul drainage underground. A well so located as to avoid dangerous pollution is shown in figure 1.

The temperature of water in deep strata is affected very little by seasonal variations in temperature. It is usually close to the mean annual temperature of the area.

SAFEGUARDING THE SUPPLY

As water moves through the water-bearing layer, soluble material, bacteria, or objects small enough to pass through the open spaces of the soil can be carried for some distance. Water flowing through the cavernous or cavelike formations common in limestone, or through rock containing joints opening at or near the surface, may carry in-

fectious pollution over relatively long distances. A sinkhole in limestone country may be the catchment basin for a spring many miles away. Farm wastes and dead animals should not be thrown into sinkholes or left where drainage from them will flow into sinkholes. How drainage into a sinkhole can pollute water in a distant spring is shown in figure 2, A.

An abundant supply of safe water on any farm is an enviable possession. It should be the owner's first responsibility to keep it safe.

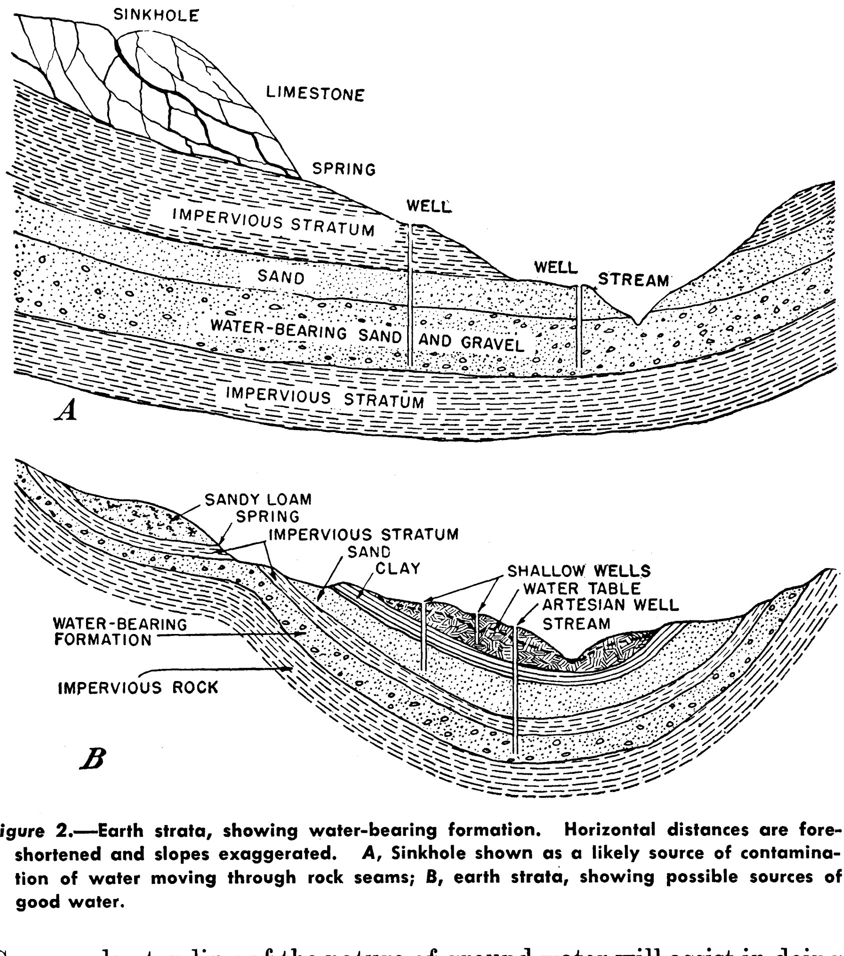

Figure 2.—Earth strata, showing water-bearing formation. Horizontal distances are foreshortened and slopes exaggerated. *A*, Sinkhole shown as a likely source of contamination of water moving through rock seams; *B*, earth strata, showing possible sources of good water.

Some understanding of the nature of ground water will assist in doing an effective job of keeping the supply sanitary. Begin by making sure that the source is clean and by removing anything that might pollute it.

Water taken from a sand, soft sandstone, or sand-and-gravel substratum can, as a rule, be expected to yield a safe supply. Even this stratum may be polluted if it is overlain by broken or highly porous rock through which surface water, drainage from cesspools, privies,

barnyards, and refuse dumps can readily pass. New wells should not be dug or driven down the slope from such places. This is especially true for shallow wells, which are not protected by an overlying stratum, or layer, of impervious rock.

Sand, soft sandstone, and mixtures of sand and gravel offer some resistance to the flow of water and filter out most of the pollution dangerous to man, provided the water passes through it for distances of 50 feet or more from minor sources of pollution[3] and 300 feet or more from cesspools, privies, sewers, and similar sources.[4] Clay offers a great deal of resistance to the flow of water and also does a good job of filtering. Water moves through it so slowly, however, that it is seldom a good source of water for the farmstead.

PROTECTING SPRINGS AND WELLS

Springs and wells should be protected from surface water. A gutter, preferably lined with concrete, should be made around the

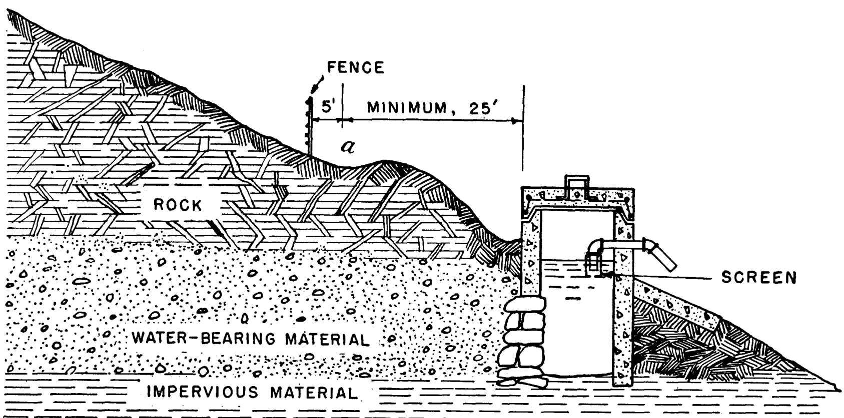

Figure 3.—**Properly constructed spring. If on ground higher than the buildings, an underground discharge pipe should be provided. Surface water is drained away from the spring by a trench (*a*).**

spring and arranged with the opening into the drain below it. This gutter should be not more than 25 feet from the spring (fig. 3, *a*). Springs should be protected from backwater from streams in flood stage. Where possible, springs should be enclosed in concrete. The cover or part of it should be removable, but water should be obtained through a pipe extending through the concrete wall. The spring should be cleaned at least once a year to remove any sand, silt, or other material. Springs should be fenced to keep out stock. The fence should be so erected that stock cannot get between the gutter and the spring.

To keep surface water and contamination out of wells is as important as it is to keep both out of springs and cisterns. Mound-

[3] U. S. Public Health Service. ground water supplies. Public Health Rpts. Sup. 124.

[4] From Ohio Dept. Health, Rural Water Supplies.

ing the earth around the top of the well will help turn aside drainage that might otherwise flow directly into it. Since only water from the water-bearing stratum is desired in the well, that part extending into this stratum is the only part that need be lined with porous material or curbed with loosely laid bricks or stones. Make that part of the well above the water-bearing layer as tight as practical.

Above the water table the dug well should be curbed with concrete or vitrified clay tile with bell ends. The joints should be sealed with a waterproof sealing compound or cement mortar. Backfill around the top four or more joints should consist of concrete, so that the protective lining will keep out surface seepage for a distance of at least 10 feet below the ground surface.

The dug well should be covered with a concrete slab that extends on all sides a foot or more beyond the well curbing. This slab should be built with its top surface sloping one-fourth inch per foot away from the pump pedestal. The pedestal should be at least 3 inches high and equipped with anchor bolts or other anchorage to hold the pump rigidly in place. The cover for the manhole should overlap and sit firmly on the manhole curb.

To overcome the inherent tendency of dug wells to admit surface water and shallow ground water and of platforms to become leaky, the buried-slab type of dug well has been developed.

CLEANING WELLS

A properly constructed well with tight cover, such as shown in figures 5, 9, 10, and 11, keeps out sunlight, surface water, insects, and animal life and seldom requires cleaning. For wells not so constructed periodic cleaning is a necessity because of the entrance of foreign matter at the top and owing to the washing in of clay and silt with the ground water.

In cleaning, first inspect the curbing, which, if weak or defective, would make entrance dangerous. This examination may be aided by a beam of sunlight reflected into the well from a mirror or by lowering into the well a flashlight or a lighted electric lamp on an extension cord. Do not allow electric cord or lamp socket to get wet. A reflector or screen above the lamp will prevent interference with vision in examining the curbing and bottom.

To determine the absence of oxygen, a lighted candle or lantern should be lowered into the well. ***Complete or partial failure to burn indicates dangerous conditions for workmen.*** Thorough ventilation of the well is the best remedy. The advice and assistance of a local fire-department official should be sought.

It if is found safe to enter the well, a ladder should be lowered and the curbing, from the top down, scrubbed with wire or other stiff brushes and rinsed thoroughly. The well should then be pumped as low as possible, and any mud, moss, or other debris dipped out. Allow the well to fill and then pump it out rapidly, repeating this operation two or three times if practicable.

Drilled wells, properly cased, seldom require cleaning, except to

remove sand. When the pump is removed, the well may be cleaned with a sand bucket. The newly cleaned well should be disinfected as described below under disinfection of wells and water.

DISINFECTING WELLS

Because of the unpredictable degree of muddiness and foreign material that may be present in a new well, it is impossible to give specific directions for its disinfection. The quantity and kind of disinfectant should be determined by the county health officer or by an expert analyst recommended by him. Follow his directions both in collecting samples and in treating the well after disinfecting.

Emergency disinfection may be done by following the directions for chlorination of drinking water. First determine the quantity of water in the well, then add the solution in the same proportions as explained under disinfection of water. Wash down the curbing with the treated water. Pump the well dry, rinse the curbing thoroughly from top to bottom, and remove all rinse water; allow the well to fill and then pump out rapidly, repeating the rinsing, filling, and pumping out two or three times if practicable.

Although the treatment will be helpful and may be all that is required, it should not be allowed to give a false sense of security. ***The user is cautioned that the water should be analyzed at the first opportunity.***

ANALYSIS OF WATER

Bacteriological and chemical analyses of water from new sources should always be made. Information on how to have this done can be obtained from the county health officer, the department of public health, or the State college or university. Water from reconditioned sources should be treated just as water from new sources.

No source of water should be accepted as safe unless proved so by test.

The United States Department of Agriculture does not undertake analyses for softness or other examinations of samples of water submitted by individuals, since its authority for work of this kind is restricted to official samples collected by the Department.

The laboratory that does the testing in your State will give complete directions for submitting samples and will probably supply containers in which to ship them. The water should be carefully collected in a sterile bottle. The sample should be representative of the whole supply, and the container should be packed with sawdust or similar material in a box or carton, to prevent breakage or freezing. The analyst will not be able to distinguish between pollution coming from the well and that getting into the sample from unsterile containers or through careless or improper handling. His directions for sampling and handling should, therefore be followed carefully. ***Having drinking water analyzed periodically is low-cost insurance against serious illness.***

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CARE AND TREATMENT OF WATER

DISINFECTING WATER

Regardless of the purity of water entering a well, it may become contaminated if the well is uncovered or only partially covered with loose planks, if it is not tightly curbed or cased and mounded to keep out surface water, if water is taken from the well with rope or chain and buckets or with open-top pumps requiring priming, and if shallow ground water is permitted to enter.

Disinfect the drinking water with chemicals only under technical direction and in an emergency. Occasionally accidents occur and steps must then be taken immediately to disinfect the water. The method used is important.

Boiling water for at least 5 minutes is an effective means of making it safe for human consumption. This is often inconvenient and is not practical on a large scale, but it can be relied upon in emergencies.

Chlorine in some form is the most dependable disinfectant. In proper quantities it destroys existing organisms, and as long as enough remains in the water to be effective it prevents recurring contamination. Since a change of water takes place gradually, the chlorine content continually diminishes to a point where it disappears or is no longer effective.

It is important to understand that, even though printed directions are closely followed, disinfection processes are not always complete. Waters of varying physical and chemical composition react differently with equal quantities of a given chemical, just as two persons may be differently affected by like doses of medicine. Clear water is usually more readily disinfected than muddy or cloudy water. Well or spring waters, however, may be clear and sparkling and yet contain so much oxidizable matter as to be little affected by an ordinary dose of the disinfectant. The sediment in muddy water or the oxidizable parts of clear water, if such be present, may use up the chemical disinfectant before the germs are killed.

Chemists and bacteriologists can determine by laboratory tests the exact quantity of disinfectant needed for each particular water. With the average individual these matters are only guesswork. He may guess wrong, and his efforts to disinfect drinking water may lead to a false sense of safety. For these reasons absolute reliance cannot be placed upon home methods of sterilizing water with chemicals, though such methods may prove useful as a temporary precaution against disease.

Emergency chlorination of drinking water may be done by (1) dissolving 1 heaping tablespoonful (approximately ½ ounce) of chloride of lime in 2 gallons of water; (2) adding 1 part of this solution to 100 parts of the water to be disinfected; and (3) allowing 30 minutes before using.

Mechanical devices for feeding chlorine into water systems are on the market. These consist of small pumps that operate at a more or less fixed rate. Some of them are driven by water power, wasting

a small part of the water; others by electric motors. The motors may be connected through the same switch as the pump motor, so that the chlorine is fed into the water only when water is being pumped. By adjusting the device and filling it with chlorine of a predetermined strength, a fairly accurate dosage can be obtained.

After it has completed its initial destruction of bacteria and of other micro-organisms, the quantity of chlorine that remains in water can be determined only by test. Satisfactory test kits can be purchased at a nominal price, and, after a little instruction, tests can be made by almost anyone who can distinguish colors.

SOFTENING

An excess of certain mineral salts dissolved in water makes it hard. Very hard water is undesirable for drinking and cooking and is ineffective and costly for cleaning and laundry purposes. It also causes a scale to form in kettles, pipes, and boilers. Water for laundering and cleaning can be softened by adding ammonia, borax, or washing soda, all of which can be obtained at most grocery stores. Water so softened, however, should be used only for cleaning and laundry purposes. Such treatment is unsuitable for softening drinking water or large quantities of water for boiler and general farm use.

Water softening is the process of precipitating or changing the form of the dissolved minerals that produce hardness. The process further seeks to neutralize the free acids that cause corrosion. It is a chemical process and therefore is distinct from filtering out such floating or settled solids as mud or silt. Filtration alone does not soften water.

The principal hardening chemicals are the bicarbonates, sulfates, and chlorides of calcium (lime) and magnesia. The principal scale-forming constituents are the carbonates and sulfates of lime and magnesia, and the usually more or less solid matter, such as mud or silt. Hardness caused by magnesia and lime carbonates held in solution by carbonic acid (carbon dioxide) can be partly removed by boiling the water, which drives off the acid, or by adding limewater or caustic lime, which neutralizes the acid. Hardness caused by the sulfates of lime and magnesia is not removed by boiling but can be partly removed by adding sodium carbonate (soda ash). Such water can be treated chemically and the precipitate removed by filtering.

A group of impurities found in alkaline waters are sodium chloride (common salt), sodium sulfate (glauber salt), and sodium carbonate (soda ash). The first two salts constitute what is known as white alkali, and the soda ash, as black alkali. These compounds are non-scale forming, but their presence in more than normal proportions makes water unfit for domestic consumption. The sodium salts are very soluble in water. They are not precipitated by heat or chemicals nor are they removed by filtration, but they can be removed by distillation.

The most satisfactory method of softening water for domestic use is to pass it through zeolite a special kind of sand. The zeolites have the peculiar ability of removing lime and magnesia from water and giving these salts up again if they are soaked in a solution of ordinary

salt (sodium chloride). The quantity of water that can be treated with a given quantity of zeolite depends upon the proportion of lime and magnesia in the water and the number of times the zeolite is renewed by being soaked in the salt solution. Several zeolite softeners are now on the market. Althought their design is relatively simple, it is not advisable for the layman to attempt to make or install them himself.

REMOVING IRON

Iron is held in solution in water by carbon dioxide. This gas is also responsible for corroding iron pipes in the water system. As long as the water is in the well or in containers where oxygen does not reach it, it is likely to remain clear. When aerated, however, or even exposed to air until the oxygen comes in contact with the iron, the iron oxydizes, forming a red sediment, or rust. The water appears red from the presence of the rust particles and is known locally as "red water." The iron oxide precipitates out and leaves the water clear when the carbon dioxide has been removed from the water either by aeration or by treating. Water containing iron is likely to cause rust spots on laundry and is undesirable for other household purposes.

Water can be aerated by forcing it through sprinklers or by pumping it to an elevated tank and allowing it to drop into a lower tank over a series of cascades. The smaller the droplets into which the water is broken the more nearly complete will be the job. After aeration the water should pass through some sort of filter, such as sand, to remove the rust particles. The sand should be replaced as required. This method of treating water has the disadvantage of requiring two pumps unless a gravity system is feasible, one for lifting water from the well and forcing it through the aerator, and the second for forcing it through the water system.

The precipitation of the iron can be hastened by adding a little limewater (the quantity determined by trial), a simple and safe solution obtainable at drug stores, or it can be easily and cheaply made at home as follows:

Put a small lump of fresh quicklime (unslaked lime) in a wooden pail and slake the lime by gradually adding about 30 times it weight of water. Stir or shake frequently for half and hour, allow time to settle, and pour out the liquid. Add to the lime residue about 300 times it weight of water, stir frequently during the next 24 hours, and allow the lime to settle. The clear water above the undissolved lime is limewater; it should be kept for use in large well-corked bottles or carboys. There is some saving if the undissolved lime is bottled with the limewater. Every time some of the limewater is used a like quantity of fresh water may be added as long as any undissolved lime remains.

Water containing iron can frequently be improved for laundry purposes by adding a little limewater or washing soda to the water in a tank or vat, stirring thoroughly, allowing the iron to settle to the bottom, and drawing off the uppermost (clear) water for use. The water drawn off should be filtered through cloth or other material, but, because of the inconvenience, this is not always done. Long boiling

of water is an aid to the precipitation of iron, but the method is generally impractical. Apparatus for the removal of iron is on the market. It is always advisable to have water tested to determine the proper treatment.

FILTERING

Filters are used to remove solid materials from the water. They are commonly used on farms for clarifying rain water passing into cisterns. Filtering does not necessarily remove bacteria or particles small enough to pass through the interstices in fine sand. Good filters are made of fine sand, wood charcoal (the pieces averaging the size of wheat grains), and gravel. In the common type of filter, water flows through these materials in the order listed. The sand filters out solid material, the charcoal removes color, taste, and odor, and the gravel prevents the loss of sand and charcoal. The sand bed should be about 2 feet thick, the charcoal and gravel each about 6 inches. As the surface sand becomes clogged, half an inch should be scraped off. Do not allow the bed to be reduced to less than 1 foot in thickness. The charcoal should be changed annually or oftener as required.

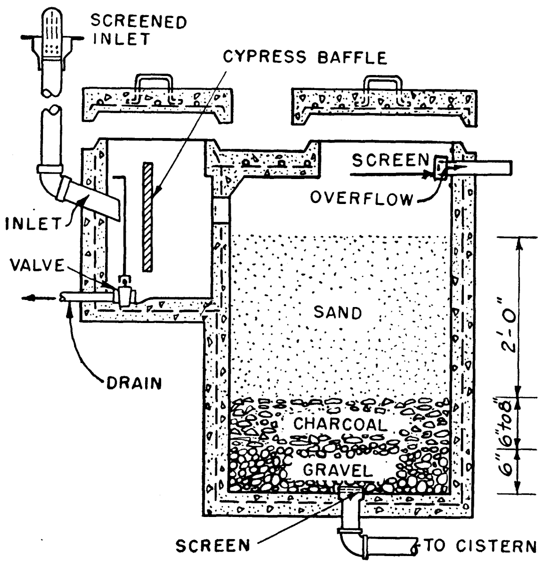


Figure 4.—**Sand-charcoal-gravel filter, used in conjunction with a cistern. Valve for diverting first part of flow from the roof not shown—it should be at some convenient point in the downspout.**

A sand-charcoal-gravel filter is illustrated in figure 4. The rate of flow through a filter of this type is about 10 gallons per hour per square foot. It is evident that the filter bed must be designed large enough to take the runoff fed from the collecting system.

If the filter is not cleaned periodically and the charcoal changed annually or oftener, it is better to use only a screen to remove trash from the water. ***Do not neglect the filter.***

The same type of filter can be so installed that the water passes upward, through the gravel first. This system, while more expensive to install, has the advantage of not acquiring an accumulation of sediment on the surface. It will in time, however, permit the charcoal to escape unless a screen is used to hold it in place.

Another type of filter consists of a porous brick wall across the cistern. This wall may be of a single thickness of porous brick laid

in watertight cement mortar with joints completely filled or two such walls 6 to 8 inches apart, with the space between filled with sand. No mortar, or only enough to prevent escape of sand, is required in the double wall. No plaster is used on the brick wall in either case. The wall should be built in a semicircle with the outside of the circle toward the inlet to prevent collapse should the rate of flow into the cistern or the rate of pumping greatly exceed the rate of filtering.

QUANTITY OF WATER REQUIRED

DOMESTIC AND LIVESTOCK REQUIREMENTS

Livestock require the same quantity of water, regardless of whether it is pumped by hand or power or is hauled to the watering place from some creek or distant well. Experience has shown, however, that stock are more likely to get an adequate quantity if the water is pumped by power and is available at all times.

Farmhouse demands, however, increase when inside toilets, bathtubs, showers, and similar fixtures are installed and when hot as well as cold running water is supplied. The demand is further increased when the domestic water supply is used to irrigate the home garden and to keep the lawn green during the hot months.

If a new water system is to be installed, thought should be given to the type and capacity required. The kind will be governed somewhat by the water supply. Assuming that this is ample, the capacity should be governed largely by the requirements as found by the experience of those who have running water in the home and around the farmstead. The following table will serve as a satisfactory guide.

Daily water requirements on the farm [1]

	Gallons		*Gallons*
Per member of family for all purposes including cooking, laundering, bath, toilet	50	Per beef cow	12
Per work horse	12	Per hog	4
Per milk cow	[2] 20	Per sheep	2
		Per 100 chickens	4
		Per 100 turkeys	7

[1] From RURAL WATER-SUPPLY SANITATION, RECOMMENDATIONS OF THE JOINT COMMITTEE ON RURAL SANITATION, Federal Security Agency, U. S. Public Health Service, Public Health Rpts., Sup. 185, 56 pp., illus. 1945.

[2] Allow 15 to 20 additional gallons per day for each cow, for flushing stables, and for washing dairy utensils.

Regardless of the precautions taken to conserve water, some is likely to be wasted by such things as overflowing tanks, excessive irrigation, and leaking faucets. A faucet leaking 30 drops of water a minute will waste as much water as would be required by a flock of 85 to 100 chickens.

To determine the quantity of water required, multiply the first entry by the number of people and the other entries by the number of animals, respectively; add these together with any that may be wasted, as indicated in the foregoing paragraph. Special provision for irrigation and fire protection will increase the requirement, depending upon the extent of irrigation and the type of protection installed.

FIRE-PROTECTION REQUIREMENTS

Few domestic water systems are designed for fire fighting. Either a solid stream in large quantity at medium pressure (250 gallons or more per minute at 40 to 50 pounds) or a fog with a relatively small quantity but at high pressure (15 to 30 gallons per minute at 500 to 600 pounds pressure) is necessary.

The use of a solid stream with medium pressure in a farmstead pumping system will require that an elevated tank be installed. It must be large to be effective. Supplying one ¾-inch nozzle at 45-pounds' pressure per square inch for 2 hours will require enough water to fill a reservoir of 700 cubic feet capacity. A tank of this capacity would be approximately 10 feet square and 8 feet deep, or 10 feet in diameter and 10 feet deep. Such a tank should be placed on a hillside with the bottom at least 110 feet (vertically) higher than the hydrant. A 3-inch pipe should lead from the reservoir to the hydrant, but if the distance is greater than 300 feet (but less than 1,000) a 4-inch pipe should be used.

An effective fire-fighting fog can be created by a modern orchard spraying outfit designed for 600-pounds' pressure per square inch and equipped with hose and special nozzle. Portable spray outfits are seldom equipped with tanks of more than 400-gallon capacity. Although a gallon of water when sprayed onto a fire as fog is said to be the equivalent of 10 gallons as a solid stream, even 400 gallons may not be enough. Provision should be made for refilling the tank quickly. Manufacturers of spraying outfits will furnish information on their use for fire fighting.

IRRIGATION REQUIREMENTS

Most irrigation of home gardens and other small plots is applied by means of sprinklers connected with domestic water systems. Garden sprinklers operate satisfactorily at 25- to 40-pounds pressure. The average lawn sprinklers use 3 to 5 gallons per minute. To be safe in determining pump capacity, estimate that each sprinkler will use 5 gallons per minute, or 300 gallons per hour. A small sprinkler will cover an area of approximately 300 square feet. About 62 gallons are required to furnish the equivalent of 1 inch of rainfall for each 100 square feet, or about 186 gallons per setting of the sprinkler.

SOURCES OF WATER

Although water seeks and flows into the lowest parts of the earth's surface, nature keeps the highlands supplied by carrying it from the lower to the higher levels in the form of vapor, which condenses there as rain or snow. Water disappears from the earth's surface by evaporation, interception (as in trenches), transpiration (through plant leaves), soaking into the soil, or by surface runoff. In both soaking and runoff it again journeys toward lower levels, forming streams, lakes, springs, and swamps en route.

GROUND WATER

Ground water has a well-defined surface, just as do creeks, rivers, and lakes. This surface is known as the water table. The sides of the stream are not well defined, as a rule, and may extend over wide areas, as does a lake in a surface stream. The slope of the water table in many cases conforms roughly with the prevailing slope of the land, but this cannot always be depended on as a guide. Water confined by layers of impervious rock may be forced to rise just as if it were flowing through a pipe and may develop a relatively high pressure. Water held beneath such rock formations is known as artesian water. (See fig. 2, *B*.)

SPRINGS

Where a surface stream erodes a channel below the water table or into water-bearing strata, water seeps out of the stream banks as springs. Springs are formed also by water passing through comparatively open joints in rock, particularly in limestone areas. (See fig. 2, *A*.) In such springs water may be polluted. Springs appearing at the bottom of a layer of sand or other comparatively fine material, as indicated in figure 2, *B*, may be safe and if properly protected are likely to remain safe.

WELLS

Unless cased with a waterproof material, a well or pit that extends down through the water table will fill to the surface of the water table. If the well penetrates an impervious layer of rock or clay into a water-bearing stratum it may fill to the top or even overflow, depending upon the pressure. Such wells are known as artesian wells. (See fig. 2, *B*.)

The quantity of water that can be drawn from a well is known as its yield. After a well has been in production for some time the yield may decrease through one or more of several causes. The extent of the water-bearing material may be limited or a small underground reservoir may be tapped, in which case the well is soon pumped dry. It may recuperate rather rapidly, but if it does not, little can be done except to drill deeper with the hope of reaching a better stratum.

Wells may be drilled, jetted, driven, bored, or dug, depending upon the earth formation and where water may be found. They also may be either shallow or deep. Shallow wells usually do not penetrate bedrock and often are supplied with water that percolates through surface material. Deep wells frequently extend through hard rock and into the underlying sand, sand and gravel, or soft sandstone.

Drilled Wells

Wells are drilled where the source of water is beneath strata of hard rock. Few farmers, however, have either the equipment or the experience to enable them to do a satisfactory well-drilling

job. It is generally recommended that construction be undertaken by professional drillers, who are equipped and experienced.

A question often asked is, How can the yield of newly drilled wells be improved? or, How can old ones be revived or rehabilitated? Definite recommendations would depend upon the workmanship of construction, the management of the well, and the water itself. The following are causes of failure in drilled wells and should be avoided at the time of construction: Failure to test properly for adequate yield, improper installation of casing, use of improper screen, faulty screen installation, unsuitable method of construction for the given formation, use of inferior materials, following too rigid or improper specifications, and employing cheap construction.

Fine sand may wash into the well or it may choke the screen and limit the yield. If sand washes into the well, it must be bailed or floated out. Solid carbon dioxide dropped into the well will cause violent bubbling and is sometimes effective in working loose any sand

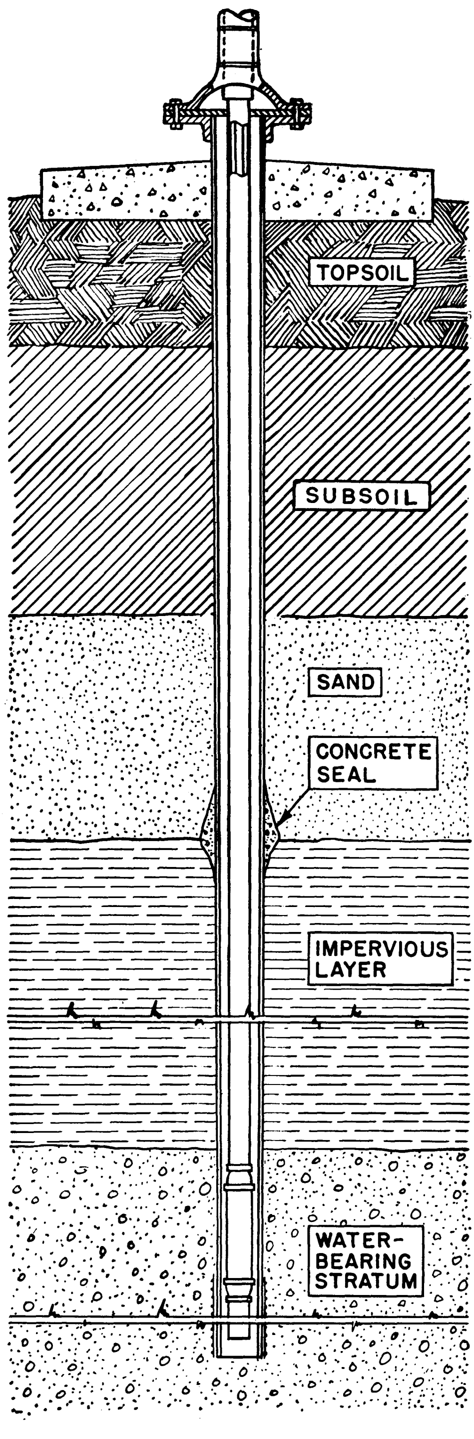


Figure 5.—**Well drilled through several soil and rock layers, or strata, into water-bearing sand and gravel. Seal is shown at top of impervious layer; also concrete platform at top of well and method of attaching pump to casing.**

that is choking the screen. It may be necessary to remove the screen if it is possible to do so. The infiltration of sand can be materially reduced by forming a layer of gravel around the screen. Professional well drillers know how this is done and can do it at the time of drilling.

The yield of drilled wells is sometimes increased by shattering the rock or other solidified material with dynamite. This is called "shooting," or "torpedoing," and may create openings to adjacent passageways carrying water. Because of the uncertain results and liability of damage to the well or loss of the existing supply, it should be employed only as a last resort.

Wells for the farmstead are drilled 2 to 8 inches in diameter, but the trend is toward wells 6 inches or more in diameter. For a given water-bearing stratum the yield is roughly proportional to the diameter. Drilled wells are cased through silt, sand, or any other loose material likely to cave in. If it is found necessary to case through drift (loose material) located below hard rock, casing a size smaller may be used. The top of the well, therefore, should be large, so that if it is found necessary to reduce the size, the bottom will not be too small. Generally it is safest to case the well all the way to the water-bearing stratum, as shown in figure 5.

Jetted Wells

Where no rocks or boulders are present, wells may be constructed by the jetting method. The three principal parts of the outfit are a well casing of the size desired, a small pipe fitted with a nozzle at one end and attached to a hose at the other, and a force pump. The work may frequently be done by hand methods, as shown in figure 6.

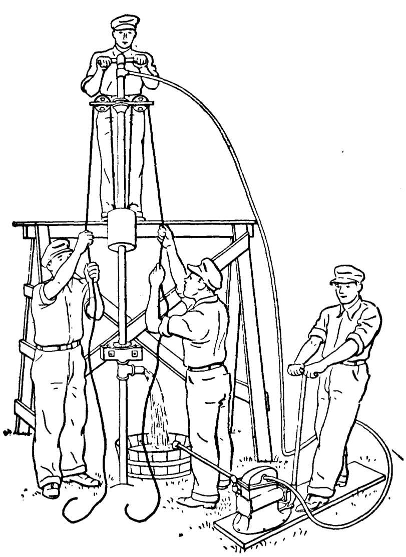


***Figure 6.*—Method of constructing a well by jetting—water is forced to the jetting tool by means of a hand pump.**

A well may be jetted down to a depth of 20 feet in a few minutes by an experienced man with two or three helpers. Water forced down through the small pipe cuts the earth loose. The earth is floated to the surface around the casing until the water table is penetrated, after which it is floated up through the casing. Water may be delivered to the site in a truck and forced through the jet with a power pump. For sandy soils, 40 pounds' pressure is adequate. But for tight clay soils and hardpan, pressures up to 200 pounds or more may be required.

The quantity of water required is usually small. A well 4 inches in diameter and 18 to 20 feet

deep can be jetted in sandy soil with 75 to 100 gallons of water. Clays and hardpans will need more. The nozzle should not project more than 2 inches beyond the lower end of the casing.

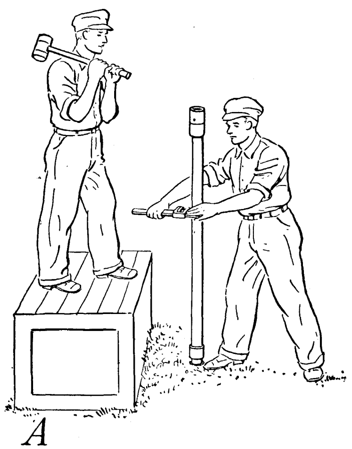
The end of the casing may be notched to give it a sawlike effect for penetrating gravel, and ordinarily a drive weight is required to force it down. The jet pipe, or inner tube, should be turned slowly while drilling, to insure a straight hole. Use a wrench that wraps around the casing, to prevent crushing.

The use of the casing as the suction-lift pipe of the pump is not recommended. If the casing is so used, it is frequently not convenient to use a weep hole to prevent freezing. The casing should be large enough to permit the use of a cylinder attached to the drop pipe of the pump. Where possible, the cylinder should always be submerged.

Driven Wells

Driven wells are common in parts of the country where water-bearing material can be reached without encountering hard rock and where water is abundant. They are less likely to receive organic impurities than shallow dug wells. Soil through which a pipe can be driven, however, cannot always be expected to protect ground water from surface contamination.

A driven well consists of iron or steel pipe forced into a water-bearing bed. In its simplest form, 2- to 3-inch extra-strength wrought pipe is cut into convenient lengths, provided with a well point, and driven as shown in figure 7, *A* and *B*.



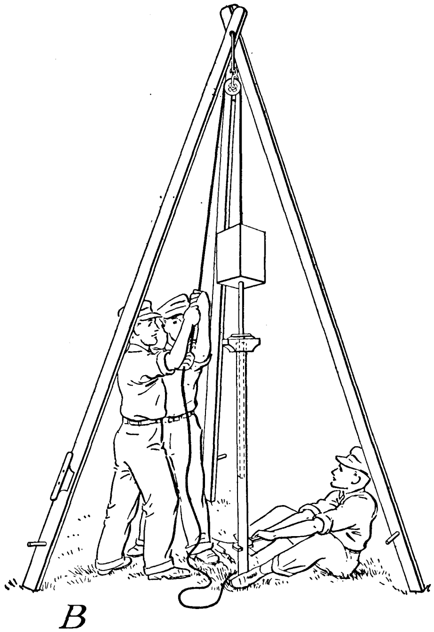


***Figure 7.*—Methods of driving wells: *A*, Using a heavy hammer, sledge, or maul; *B*, using a drive block, raised by rope and pulley—its fall is guided by a spindle that extends down inside the drive pipe.**

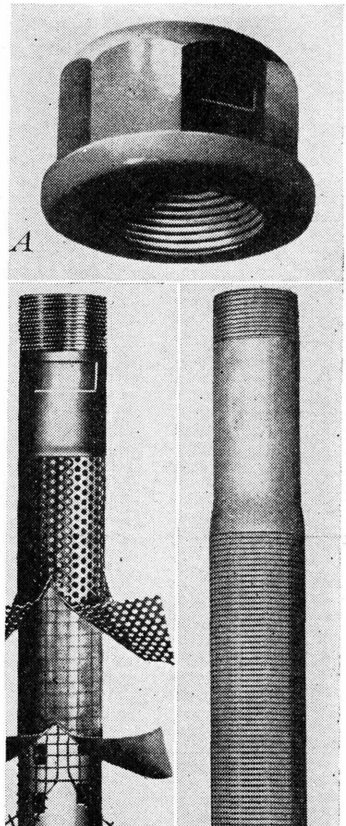


Figure 8.—**Drive-well points: *A*, Drivehead; *B*, screen and perforated jacket, cut and bent back to show construction; C, point with continuous spiral screen.**

Drive-well points consist essentially of a forged steel point, a screen, and a short section of pipe threaded to fit a standard pipe coupling. The top of the drive pipe must have a heavy cap, or steel drivehead (fig. 8, *A*), to prevent battering the pipe when it is driven. All pipe joints should be coated with red lead or graphite and oil and screwed together tightly with pipe wrenches. Otherwise the threads may be stripped or the couplings split.

Two commonly used types of drive-well points are shown. In one of these (fig. 8, *B*), the screen is made up of a piece of pipe containing several rows of round or square holes, around which a screen of proper mesh is wrapped; a perforated metal jacket covers the screen for protection during driving. In the other (fig. 8, *C*), a forged point is attached to a short section of pipe by means of several parallel rods. These are wrapped with a continuous strand of triangular wire, wound spirally from top to bottom, a flat side out, forming a continuous slot. The angle of the wire opposite this side is welded at each contact with a rod, making the outside flat. The space between the turns is thus wider on the inside than on the flat outside, so any sand fine enough to enter this narrow slot will be drawn through without clogging.

If the screen becomes corroded or choked, the well must be abandoned or the point pulled, the screen cleaned, and the point redriven. Nonferrous metals are used to reduce corrosion. Manufacturers claim that these not only withstand the corrosive action of certain waters better than iron or steel but also can be acid-treated if they become incrusted.

Bored Wells

Water is sometimes obtained quickly and inexpensively by boring a well with an earth auger. The auger may

be turned and lifted by hand or by mechanical means, such as a post-hole-auger attachment for the farm tractor. This method of boring if done by hand is limited to small diameters, and even with mechanical power it is limited to shallow wells in relatively soft materials free from boulders. Wells up to 24 inches in diameter may be bored with mechanical outfits. Bored wells are cased with standard well casing.

Dug Wells

When shallow wells are dug, one or two men at the bottom loosen the earth and shovel it into buckets, while one or two others at the top lift the buckets with a windlass.

In unstable material considerable care must be exercised to prevent cave-ins, which may result in serious or fatal injury.

In loose sand that yields an abundance of water, excavations can sometimes be made by pumping. A section of curbing with a sharp edge at the outside is started down and gradually sinks as the sand and water are pumped from the bottom and additional curbing is set on top. Care must be exercised to keep the curbing vertical.

Quicksand is a frequent source of trouble. Its flow can be largely prevented by removing the material with an orange-peel bucket or a centrifugal pump and keeping the excavation partially full of water. This neutralizes the hydraulic pressure in the quicksand and renders it comparatively solid. If the material must be excavated by hand methods, the lower, or cutting, edge of the caisson, or curbing, should be kept 1 to 4 feet below the bottom of the excavation. Wood may be used for the caisson and steel or concrete for permanent curbing; its sides should be watertight.

After the excavation is completed, further entry of quicksand at the bottom can be prevented by placing a thin layer of clean coarse sand and weighting it with several layers of sand or gravel of increasing coarseness. There is thus created a graded sand filter, each layer of which is held in position by the slightly coarser material above it.

Well curbs may be of stone, brick, concrete block, poured concrete, vitrified tile, or corrugated pipe. Wood soon decays and should not be used. At least the upper 10 feet of masonry curbs should be laid in cement mortar to make them watertight. Considering cleanliness, tightness, durability, and cost, perhaps no curbing is better than vitrified sewer pipes or hard-burned drain tiles. Sometimes the pipes are placed with the bell downward, but such arrangement makes it impracticable to cement the joints. The space between the curb and the sides of the excavation should be filled with clean sand and gravel up to the top of the water-bearing stratum, the coarser material at the bottom. Surface water will be prevented from moving down along the concrete casing if puddled clay or concrete is used to backfill, as shown in figure 9. The curb should be brought at least 1 foot above the ground and be surmounted by a concrete platform in which is cast a manhole and pump stand. The manhole should have a tight-fitting iron or concrete cover.

Although farm labor for digging represents little actual outlay of money, the cost of a dug well properly constructed is often greater than that of a drilled well.

If a pump is to be set on the platform, a short piece of well casing may be embedded in the concrete to provide an opening for the drop-pipe and cylinder. A firm, watertight joint between the pump base and the concrete is made by using expansion bolts or anchor bolts and a gasket. Expansion bolts are screwed through the pump base into holes in the concrete. Anchor bolts to fit the holes in the base

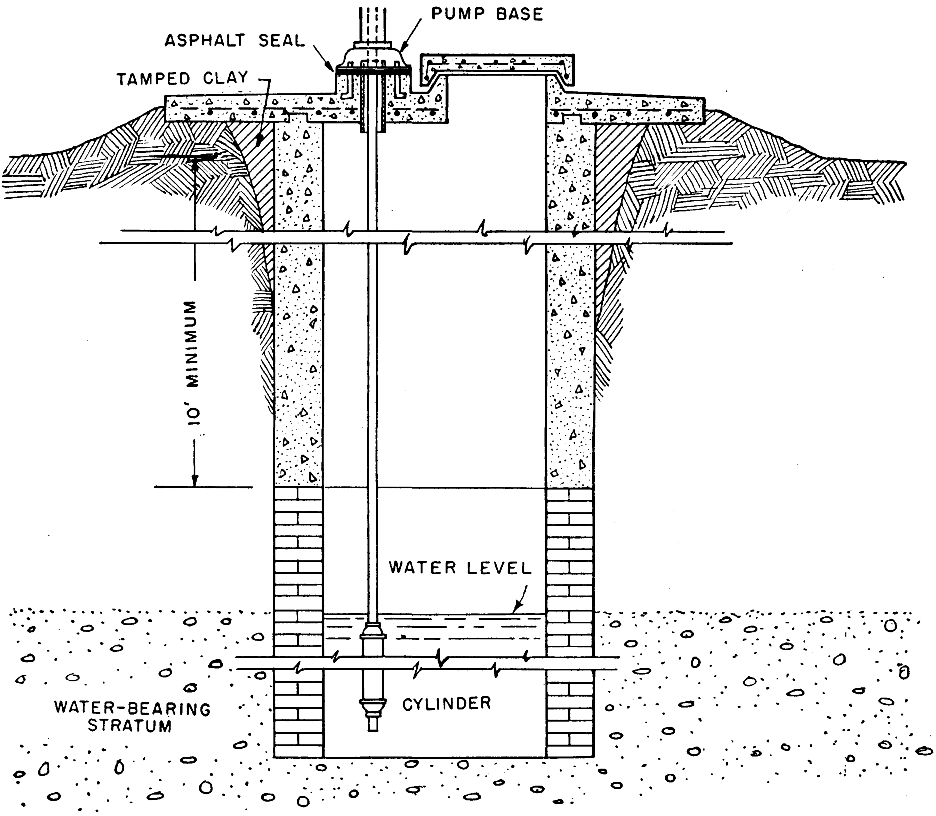


Figure 9.—Dug well properly constructed, with sides sealed down at least 10 feet from the original ground level.

are embedded in the concrete when it is poured. Ordinary bolts with the thread end up and a large flat washer on the head in the concrete will answer the purpose.

Another form of dug well is known as the buried-slab well (fig. 10). The 8-inch slab, extending 18 inches beyond the well on all sides, may be precast and lowered into place on top of the curb with an automobile-wrecking derrick. The slab must be reinforced and should have three or four loops of ½-inch or larger iron, cast into it at equidistant points, to facilitate slinging. Use the equivalent of a 1–2–4

mix. Place ½-inch reinforcing rods 5 inches apart, both directions, 2 inches from the bottom, before pouring the concrete into the form.

Dug wells properly located, constructed, and protected are more likely to be satisfactory than any other type except drilled wells. The advantages are that they have longer life and larger volume, thus permitting more rapid pumping, lower lifts, and easier inspec-

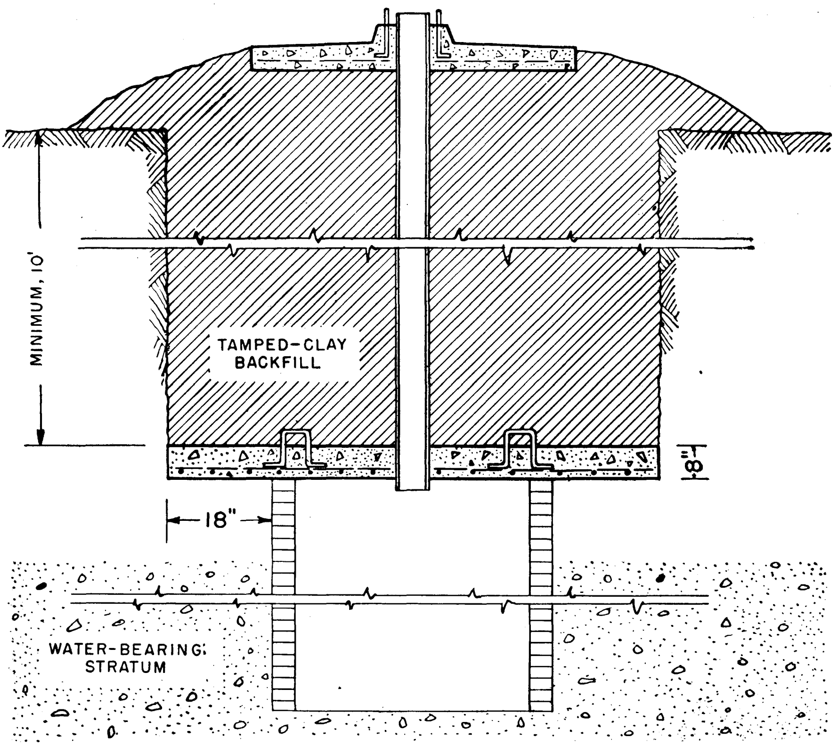


Figure 10.—**Buried-slab well.**

tion and cleaning, with less trouble from quicksand and air leaks. Some of the disadvantages are susceptibility to pollution from surface sources and the likelihood of going dry during protracted drought.

Reconstruction of Dug Wells

In the light of information on the effects of poor-quality or even dangerous water, many farmers may wish to improve their wells. Dug wells are usually large enough to permit the insertion of vitrified clay tiles and to allow space for fill between them and the original earth. One method of doing this is shown in figure 11. Joints in the tiles should be effectively sealed with cement down to at least 10 feet from the top.

The old well should be emptied and thoroughly cleaned before reconstruction begins. It should be treated as a new well when

finished. Before reconstructing an existing well it should be determined whether the water supply is adequate, safe, and satisfactory as to location. Nothing is gained in reconstructing a well that will not meet all these requirements. It would be better to fill it up, as explained elsewhere (p. 23), and to construct a new well.

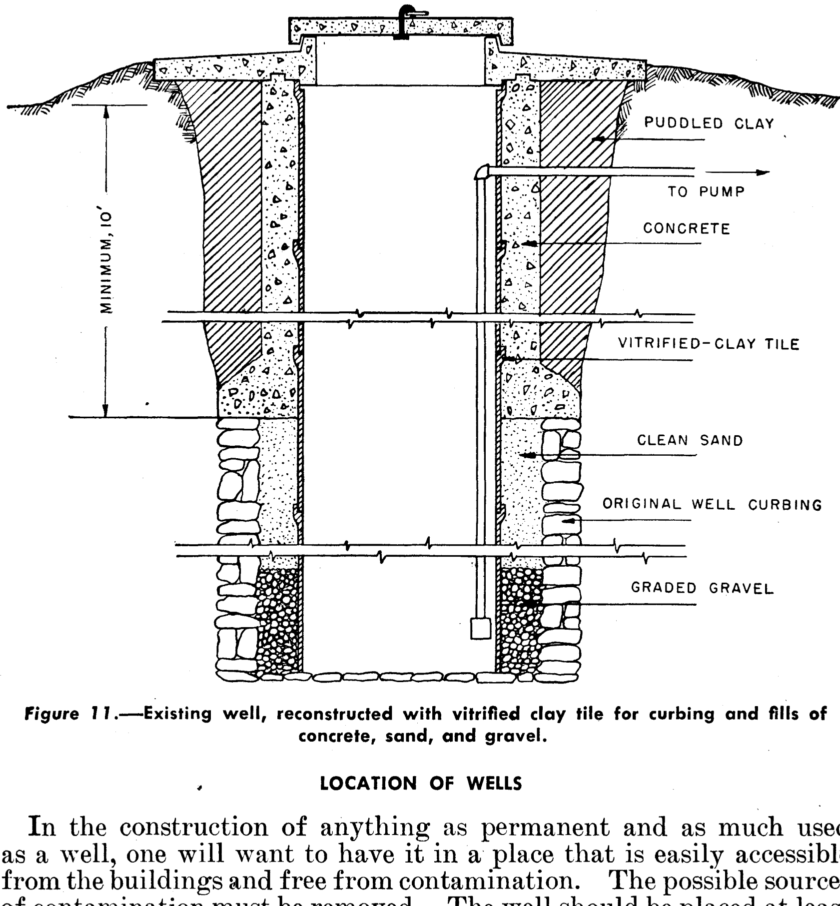


Figure 11.—**Existing well, reconstructed with vitrified clay tile for curbing and fills of concrete, sand, and gravel.**

LOCATION OF WELLS

In the construction of anything as permanent and as much used as a well, one will want to have it in a place that is easily accessible from the buildings and free from contamination. The possible sources of contamination must be removed. The well should be placed at least 300 feet, farther if practicable, from sources of pollution and in the direction from which the water moves. It should be on the opposite side of the house from the sewerage system. (See fig. 1.)

The basement of the house is usually considered a poor location for the well or cistern, because there is always some dampness around them. Many basements are subject to flooding and consequent contamination. Moreover, in a basement it is not practicable to have a clear space above the well for the removal of the pump, pump rod, or well casing. The well should not be under electric power wires because of the danger of touching them when any of these parts are being removed.

No reliable general directions can be given for locating ground water. Experience of neighbors and careful observation of their wells may be helpful. Advice of the State geologist, hydraulic engineer, or other competent officer should be sought. The State college or university also may have useful information. Experienced well drillers can often give accurate advice. Many wells have been sunk to great depths in the belief that a plentiful water supply would be reached, but no water was found, or the water was unfit for use. Often such deep holes serve only to drain water from the surface or from relatively near it.

Information as to the kind, thickness, porosity, and dip of the strata of the region, the results obtained in neighboring wells, and examination of the land slopes, vegetation, and evidences of seeps and springs serve as good guides in locating a water supply. There is little to recommend certain patented electrical water finders or the use of a forked willow, hazel, or peach stick, although so-called forked-stick artists, from their experience and observation of surface conditions, usually are better able than the average person to judge of the probabilities of finding ground water.

ABANDONING WELLS

In time the covers of neglected wells become unsafe, and animals or children may break through and lose their lives. Trash and rubbish or dead animals dropped into old wells may contaminate the water supply of some neighbor who obtains water from the same ground-water source. Abandoned wells should be completely refilled with clay, well tamped to prevent the entrance of surface water.

SURFACE WATER

Surface water and water passing through surface soil are likely to accumulate impurities that render them dangerous for human consumption unless first treated or boiled. Many springs and shallow wells are supplied with surface water or water that passes through only loose soil, rock crevices, or channels formed by dissolving minerals or rocks, such as caverns or caves in limestone. All water, and especially surface water, should be analyzed by a representative of the State or local health office or other qualified analyst and have his approval before it is used.

Water from streams should never be used for human consumption unless it is pronounced safe by qualified persons. Such water should be checked periodically to insure the user that it has not become polluted, since unprotected supplies are subject to pollution. It is advisable to install a continuous chlorinator in the water system where water for domestic purposes and for stock is taken from surface streams and ponds.

Water collected from roofs of buildings and stored in tanks or cisterns also belongs to the general class of surface water. Although rain water may pick up impurities from the air while falling or the drops may even form around particles of dust, it is usually relatively free from contamination until it reaches a roof.

Since the daily water requirements indicated on page 12 are not continuous over the entire 24-hour period and rather heavy demands are made at certain times of the day, provision must be made for the peaks. There would be no advantage in purchasing a pump having larger capacity than the peak demands unless the tank or reservoir into which it discharges is comparatively large. On the other hand, a pump large enough to supply the total requirement in 4 hours' operation will wear longer than a smaller one that requires 6 hours to do the same job.

The pressure on the surface of a liquid which at sea level is approxi-

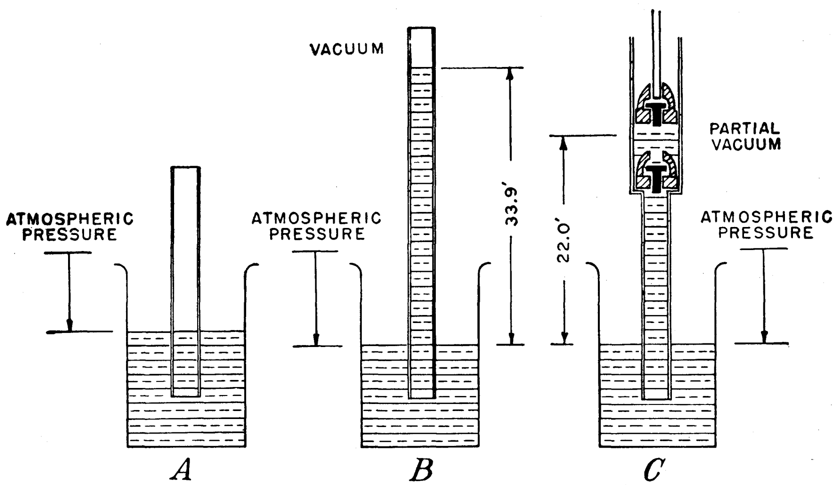


Figure 12.—**Suction lift caused by atmospheric pressure.** ***A,*** **No lift or rise inside tube when pressure inside and outside are equal;** ***B,*** **suction lift, with complete vacuum inside tube (theoretical);** ***C,*** **suction lift of pump with partial vacuum inside tube.**

mately 14.7 pounds per square inch, will force it to rise into any pipe or chamber from which all or most of the air or other content has been removed. The elevation to which the liquid will be forced up into the vacuum will be that at which the weight of the column will equal the pressure of the air on the surface of the water outside the pipe. For water at sea level this elevation is approximately 34 feet. The process of removing the air or liquid, allowing the air pressure to force a liquid to rise in a pipe, is known as suction lift. This action can be demonstrated by pulling a snug-fitting plug through an air-tight tube, the end from which the plug moves being set in water (fig. 12). The practical suction lift for pumping should not be more than 22 to 25 feet at sea level. At higher elevations the atmospheric pressure is lower, hence the suction lift is less.

TYPES OF PUMPS

Pumps may be divided into five types: Plunger or reciprocating, turbine, centrifugal, rotary, and ejector. They may also be divided into shallow- and deep-well pumps. Shallow-well pumps are occasionally referred to as lift, or suction, pumps.

The plunger pump is sometimes called a "positive-displacement" pump. Such pumps will build up pressures as long as they continue to operate. The rotary pump is also a positive displacement pump.

Centrifugal and ejector pumps develop pressure by centrifugal action and cease to build it up beyond given limits, depending upon their design and speed. The pressure beyond which these pumps will not force water is called the "shut-off" head. The discharge from centrifugal pumps can be regulated by means of a valve in the discharge pipe, but it should not be completely stopped in this way.

Some other mechanical means of lifting water are air-lift and air-displacement pumps, chain pumps, propeller or screw-type pumps, helical rotor pumps, hydraulic rams, and siphons. Air-lift and air-displacement pumps are usually not efficient and are not often used. Chain pumps are not considered so sanitary as force pumps and are not very efficient. The propeller, or screw-type, pumps are used for lower lifts and larger volumes than are ordinarily required for domestic use. Hydraulic rams are automatic but wasteful, obtaining power from the water supply. Siphons are used to carry water over an obstruction to lower levels.

PLUNGER PUMPS

The plunger pump simply forces the air or water out of the chamber when the plunger is forced in and creates a vacuum when the plunger is withdrawn. The plunger when made in the form of a piston drives the air or water out of more space and creates a larger vacuum than if a simple plunger were used. When so constructed, it is possible to have the piston head act as a plunger in either or both directions. When it performs the cycle only at one end, the pump is known as single acting and when both ends of the cylinder are used, the pump is known as double acting (fig. 13).

The double-acting type of pump is usually placed at the top of the well, the suction pipe extending down into the water. It is also known as a shallow-well pump, and its use is limited to wells of that type or to wells where the distance to the pumping surface is less than 22 feet. The suction pipe need not necessarily be straight, but if the pump is not set directly over the well, the run from the well to the pump should always slope upward toward the pump. The pump should not be more than 500 feet from the well, because of pipe losses.

Deep-well pumps may also be of the plunger type, but the plunger and valves are set close to or beneath the surface of the water. The plunger is connected with the working head by means of a pump rod, as shown in figure 14, *A*. Pumps of this type are usually single acting. As the plunger, in which the upper valve is located, moves upward,

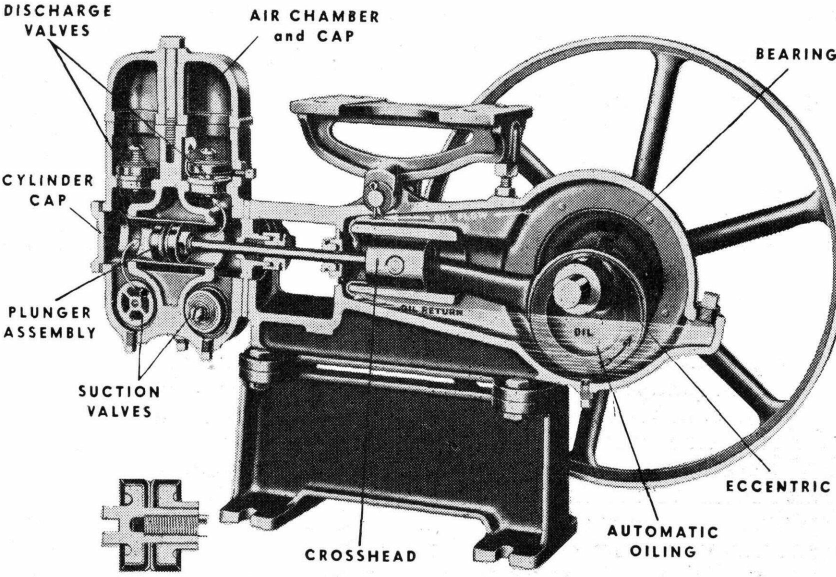


Figure 13.—**Shallow-well pump, showing working parts. As piston moves toward right, water is drawn into the cylinder at the left and the water at the right is forced out through the discharge valve, as shown by the arrows.**

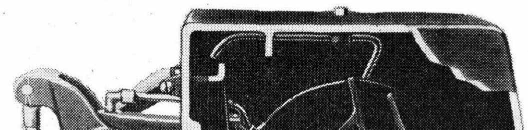


Figure 14.—**Working head of a deep-well pump: *A*, Pump rod; *B*, pump for supplying air to pressure tank.**

the water on top of the valve is forced upward through the drop pipe and another charge of water fills the space between the valves. The cycle is repeated with each upward stroke. Because of the pump rod it is necessary to set this pump directly over the well.

TURBINE PUMPS

The turbine is one of the simplest of all pumps. It consists essentially of a bronze disk, firmly mounted on a drive shaft, and a close-fitting case. The outer edge of the disk is slotted, as shown in figure 15. The disk rotates in a channel formed by casing liners

with very small clearance. Rotation of the disk forces the water to move with it, carrying it from the inlet to the discharge. Turbine pumps may be set with the shaft either horizontal or vertical and are designated horizontal or vertical, accordingly.

The horizontal type is often installed in shallow wells, but in deep wells the motor is mounted vertically and a shaft extends down into the well to below low-water level, where the impeller disk is mounted. In many wells one impeller may not develop enough pressure to deliver water to the top of the well and against the pressure

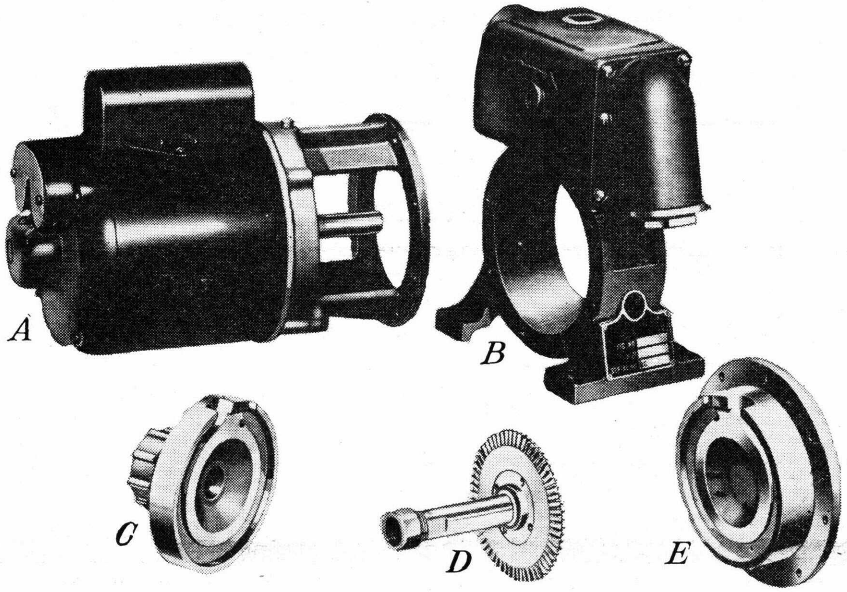


Figure 15.—Turbine pump: *A*, Electric-motor assembly; *B*, pump frame; *C*, end bearing and ring liner; *D*, runner with slots cut into rim of disk; *E*, outboard end and ring liner.

of the tank. In cases of this kind additional impellers are used in numbers sufficient to develop the desired pressure. Each impeller operates in its own channel and has its own casing liners. In fact, it amounts to several pumps in series, one discharging into the next, each increasing the pressure until it is high enough to discharge over the top of the well or into the pressure tank.

CENTRIFUGAL PUMPS

The centrifugal pump is perhaps the simplest of all pumps. It consists of one moving part, an impeller made up of a hub from which radiate blades usually curved backwards toward the tips. The impeller operates in a close-fitting housing. It may be open or the blades may be mounted between disks, forming what is known as an enclosed impeller.

Water enters the impeller from one or both sides at the hub and is thrown out by centrifugal force. The casing has a volute, or snail-like, passage extending around the impeller. This passage begins very small and increases in cross-sectional area to the discharge. Water moving out through the impeller creates a vacuum at the center.

Centrifugal pumps of the conventional type must be primed. They are not designed for high-suction lifts and so are usually set near the water's surface and operated with foot valves that keep water in the suction pipe. The pressure at the discharge end depends upon the speed and diameter of the impeller. The volume depends more upon the width of the impeller and size of water passage. Centrifugal pumps are water lubricated and as such are subject to wear if the water carries abrasive material. If, however, the water is free from such material, centrifugal pumps will last a long time.

Centrifugal pumps, like rotary pumps, may be set with the shaft either horizontal or vertical. They also take their designations from the position of the shaft.

ROTARY PUMPS

The rotary pump is frequently called a gear pump. It is simple in design but is subject to considerable wear, particularly when it pumps water containing an appreciable quantity of sand or other abrasive. It is used a great deal in pumping oil or other lubricating liquids that are free from abrasive material. Water enters at the bottom (fig. 16) and fills the spaces between the teeth and is carried out around to the top, where it is forced out when the teeth mesh with those of the opposite gear. The pump delivers a steady flow of liquid without pulsation. It is a positive pump and will operate against any pressure that the equipment can stand.

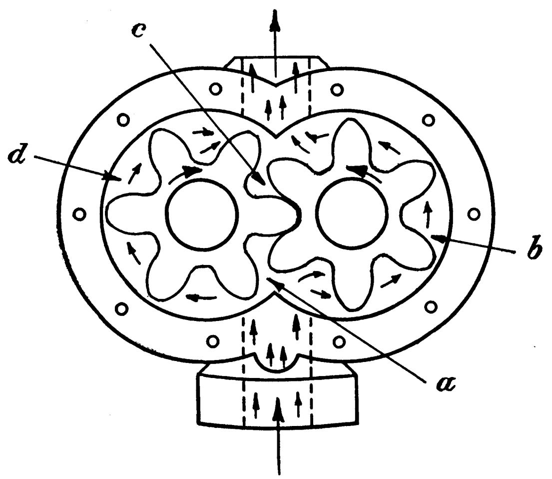


Figure 16.—**Rotary pump: Water entrapped between teeth at *a* is carried around as at *b*, and is forced out at *c* where the teeth mesh with those of the opposite gear.**

EJECTOR PUMPS

The ejector, or jet, pump is relatively new. It is made in

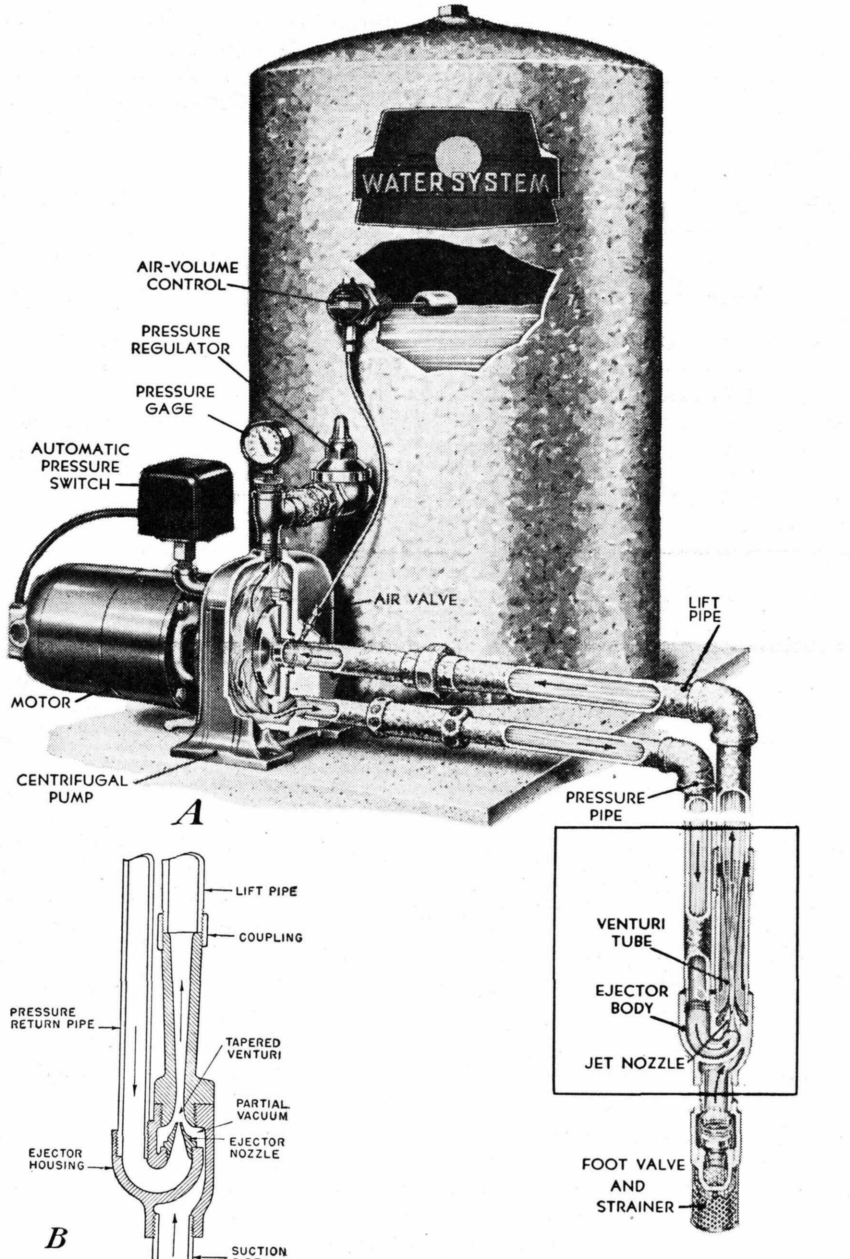


Figure 17.—**Ejector pump, showing, *A*, that part of the water is used to operate the ejector (pump not necessarily mounted directly over well); *B*, enlarged view of ejector as shown in rectangle in *A*.**

both shallow- and deep-well models, the latter being satisfactory for depths to 85 feet. The ejector pump consists of the same moving parts as the centrifugal pump, but part of the water from the delivery side of the pump is piped down into the ejector, as shown in figure 17, in essentially the same manner as live steam is used in an injector to feed water into a steam boiler. Water flows in the directions indicated by the arrows. The nozzle opening enlarges with use, hence requires more water, leaving less for the tank. The nozzle should be replaced when this happens.

Operation of the pump is somewhat that of two pumps working together, one discharging into the other. Assume that the pump is primed and operating. Water under high pressure is delivered to the jet, or ejector nozzle (fig. 17, *B*). As the water at high velocity leaves the jet and passes through the venturi tube a partial vacuum is created around the nozzle. Water flows into this space and is caught up by the fast-moving stream and carried into the expanded end of the venturi tube, where it is mixed with the stream from the jet. As the tube expands, the velocity head changes to pressure head, which lifts the column of water up to an elevation at which the vacuum created by the centrifugal pump at the top of the well takes effect. The centrifugal pump again develops a pressure head, delivering some of the water to the storage tank or pneumatic pressure tank and the rest, or a metered part, back to the jet to repeat the cycle.

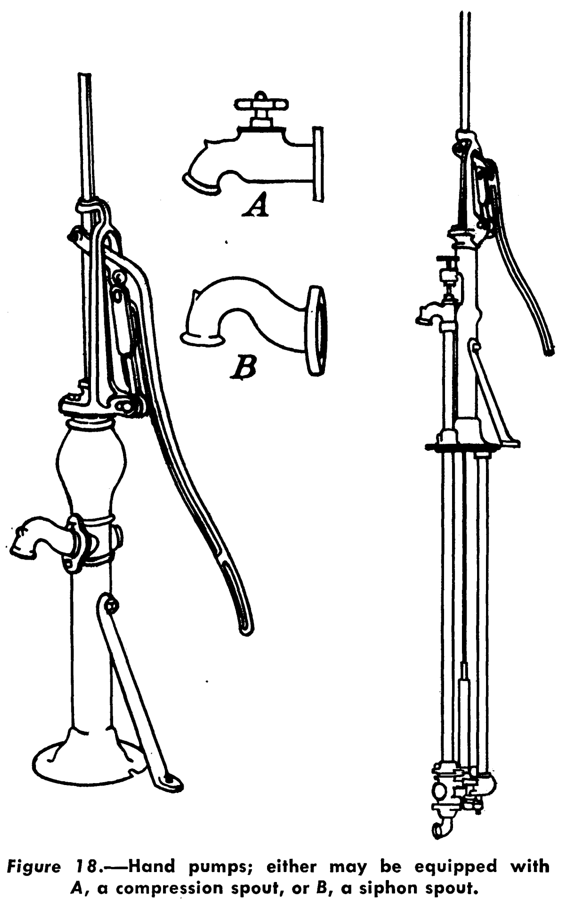


Figure 18.—**Hand pumps; either may be equipped with *A*, a compression spout, or *B*, a siphon spout.**

Since no moving parts extend into the well, it is not necessary to install the pump directly over it. It is advisable always to arrange the suction pipe so that if not installed vertically it slopes upward at all points. In many ways the ejector pump has some distinct advantages over other types of pumps. For example, it is adaptable to conditions requiring that the deep-well pump be installed at

some distance from the well, it is simple in construction and quiet in operation, it is suitable for use in relatively small wells. If the well is too small for parallel pipes it is possible to place the suction pipe inside the pressure pipe, although this may somewhat increase the installation cost.

HAND PUMPS

Hand-operated pumps in wide variety are on the market. While no attempt is made at recommending one type above another, a word of caution is offered. Whatever pump is purchased should be completely enclosed (fig. 18). The open-top pitcher type is not recommended for pumping water for human consumption. Use a force pump or a pump with a packing gland where the rod enters, so that unsafe water cannot enter the well; submerge the cylinder where possible.

If a windmill is used, the pump should be one that can be operated by hand or with a power jack. This can easily be done by using an extended pump rod to which either the windmill rod or the jack can be attached. Be sure that the length of stroke of the windmill or power jack is within the working limits of the pump cylinder.

Be sure to remove the pin that connects the pump handle with the rod; otherwise someone may be seriously injured.

HYDRAULIC RAMS

Ordinarily an automatic electrically operated pump is the most economical and reliable means of providing running water for the

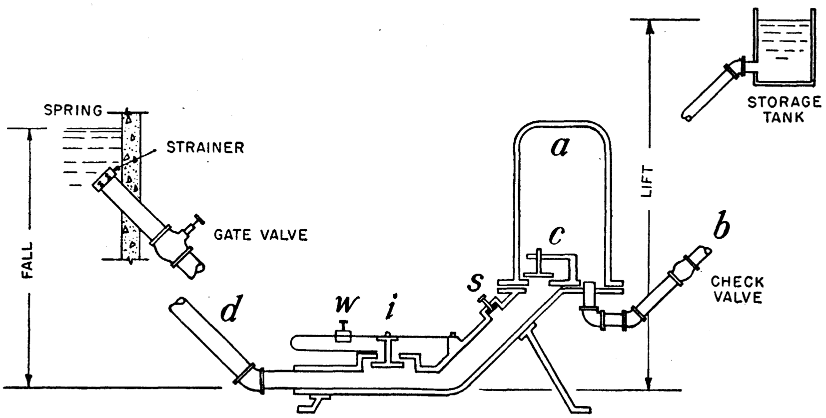


Figure 19.—**Hydraulic ram: *a,* Air chamber; *b,* delivery pipe; *c,* check valve; *d,* drive pipe; *i,* impetus, or waste, valve; *s,* snifter valve; *w,* movable weight.**

farm home and other farm buildings. Under some conditions, however, a hydraulic ram can be used advantageously. This device utilizes the long-known principle of water hammer. The essentials of its operation are outlined in figure 19 and briefly described as follows:

Water flows from the source of supply, as a spring, through a straight iron pipe *d*, wasting through impetus valve *i* until the

velocity is sufficient to force the valve upward to its seat. This creates a "kick," or water hammer, in pipe *d* and opens check valve *c*, through which some of the flow is forced into air chamber *a* and delivery pipe *b*. The greater pressure in pipe *b* quickly overcomes the movement and causes a reaction or backward pulsation, closing valve *c* and unseating valve *i*, whereupon the water in pipe *d* flows again and the whole operation is repeated. On the recoil, a little air is sucked through the snifter valve *s* to maintain the supply in chamber *a*.

The hydraulic ram is wasteful of water and should not be used where the supply is limited. The quantity of water that may be raised to a given elevation with a given fall is shown in table 1.

TABLE 1.—*Gallons of water lifted by hydraulic ram per gallon received from source*

Fall (in feet)	Height delivered (in feet)							
	12	18	24	30	36	48	60	72
2	0.1							
4	.18	0.15	0.1					
6	.33	.2	.17	0.13	0.1			
8	.42	.28	.2	.17	.15	0.1		
10	.54	.36	.27	.22	.18	.14	0.1	
12	.67	.44	.33	.26	.22	.16	.13	0.1

The double-acting hydraulic ram was designed to utilize the energy from one source to lift water from another, thus permitting the flow from a creek to drive water from a spring to the desired delivery point. This, however, is not free from the danger of mixing and contaminating the good water.

Manufacturers of rams require the following information to determine the size needed for a particular installation: (1) Quantity of water in gallons per minute available at the ram, (2) quantity in gallons per day desired at buildings, (3) available fall in feet, (4) horizontal distance in which fall occurs, (5) length of delivery pipe, (6) lift in feet. Manufacturers' instructions for installing should be closely followed.

SIPHONS

Occasionally one is fortunate enough to have a hillside well or spring from which water can flow by gravity. The surface of water in the spring may be near enough the ground surface to take advantage of gravity all the way, but the surface of the water in the well may be some distance below the ground surface. If it is less than 20 feet a siphon can be used to lift the water over the top for delivery to a point below the upper water level. The point of discharge must be ***lower than the water level at the source.***

The siphon operates as an airtight, inverted **U**-tube. The flow through the discharge leg of the siphon tends to form a vacuum in the other leg, which immediately fills with water if the distance from the water surface to the top of the siphon is not too great. The theoretical height to which water can be raised with a siphon is identical with

that of a leak-tight pump, but because of pipe friction, air leaks, and vapor pressure, the siphon can seldom be relied upon to lift water more than 20 to 25 feet.

The elimination of air leaks is necessary. Pipe joints must be effectively sealed, because even a slight leak may be enough to break the vacuum and cause the siphon to fail. The siphon can be primed by attaching an ordinary shallow-well pump at the lower end, priming and operating as if pumping from a well. Once the flow is started, it will continue indefinitely without pumping if the water level at the inlet remains unchanged. Water should not be drawn off too rapidly—the pipe must always be completely full. Pipe friction must be considered in a siphon just as in a pump. The intake must be far enough below the water surface to prevent air from entering.

SELECTION OF PUMPS

In selecting a pump, first consideration must be given to its duty. The pump should have sufficient capacity to supply the farmstead water requirements, up to the yield of the well. Location and type of power also are factors. If the power is from a windmill a plunger pump is the only practical kind.

Plunger pumps will deliver water in quantities proportional to the number of strokes and the length and size of the cylinder. They are adapted to wide ranges of speeds and to practically any depth of well and at depths exceeding 65 feet are likely to be somewhat more efficient than other types. Since plunger pumps are positive, they should be fitted with automatic relief valves to prevent rupture of pipes or other damage should power be applied against abnormal pressures.

If it is not practical to set the pump directly over the well, as is necessary with the deep-well plunger pump, an ejector type of pump should be selected. The ejector pump is most efficient where the lift is between 25 and 65 feet, but it will operate with lifts of 120 feet. The ejector pump is not usually recommended for wells where the depth to water is more than 85 feet.

Centrifugal pumps are somewhat critical as to speed and should be used only where power can be applied at a reasonably constant speed. They must be mounted close (6 to 8 feet) to the pumping surface. Vertical-type centrifugal pumps are used in deep wells. They are driven through shafting by vertical motors mounted at the top of the well. Rather large wells are required for either centrifugal or turbine deep-well pumps, the size depending upon the capacity and design of the pump.

Centrifugal pumps are efficient in the higher capacities, but in the lower capacities, 10 gallons or less per minute, their efficiency is not so high as that of the plunger pumps. It is usually not practical to adapt them to jobs requiring these small volumes of water. They are at their best when pumping for irrigation, city water systems, and other large volumes.

Turbine pumps, as used in domestic water systems, are self-priming. Their smooth operation makes them suitable for installing where noise and vibration must be kept at a minimum.

Ejector pumps are becoming very popular. They operate quietly, and neither the deep- nor the shallow-well type need to be mounted over the well.

A brief tabulation of characteristics of various types of pumps follows. For convenience they are listed as advantages and disadvantages. For some uses certain characteristics listed as disadvantages may be advantages, and vice versa for others.

Advantages	*Disadvantages*
Plunger type:	
Positive action (force)	Discharge pulsates
Wide range of speed	Subject to vibration
Efficient over wide range of capacity	Deep-well type must be set directly over well
Simple construction	Sometimes noisy
Suitable for hand or power operation	
May be used on almost any depth of well	
Discharge relatively constant regardless of head	
Turbine type:	
Simple design	Must have very close clearance
Discharge steady	Subject to abrasion damage
Suitable for direct connection to electric motor	Not suitable for hand operation
Practically vibrationless	Speed must be relatively constant
Quiet operation	Must be set down near or in water in deep well
May be either horizontal or vertical	Requires relatively large-bore well
Centrifugal type:	
Simple design	Low efficiency in low capacities
Quiet operation	Low suction-lift (6 to 8 ft.)
Steady discharge	Must be set down near or in water
Efficient when pumping large volumes of water	Requires relatively large-bore well
Suitable for direct connection to electric motor or for belt drive	Not suitable for hand operation
May be either horizontal or vertical	Discharge decreases somewhat as discharge pressure increases
Rotary type:	
Positive action	Subject to abrasion
Occupies little space	Likely to get noisy
Wide range of speed	Not satisfactory for deep wells
Steady discharge	
Ejector type:	
Simple construction	Jet nozzle subject to abrasion and clogging
Suitable either for deep or shallow wells	Limited to wells 120 feet or less in depth
Need not be set directly over well	Discharge decreases somewhat as discharge pressure increases
Quiet operation	
Especially suitable for use with pressure system	
Chain type:	
Simple	Inefficient
Easily installed	Limited to shallow wells
Self-priming	Likely to be insanitary
Hydraulic ram:	
Simple design	Wastes water
Low cost	Likely to be noisy
Uses water for power	Not satisfactory for intermittent operation
Requires little attention	
Siphon:	
Low cost	Limited to moving water to lower levels
Requires no mechanical or hand power except for starting	Requires absolutely airtight pipes

INSTALLATION OF PUMPS

Pumps should be mounted on solid foundations, preferably concrete, large enough to prevent movement. Anchor bolts should be firmly embedded in the concrete and should be as large as the holes in the pump base will permit. Deep-well plunger-type pump heads must be mounted directly over the well to allow the drop pipe and pump rod to operate properly. Vertical motors for use with deep-well turbine and centrifugal pumps must be mounted carefully. The shafts of these motors must coincide with the center line of the drop pipe. Slight deviation from this will cause unnecessary wear and possibly heating. Guide bearings as recommended by the manufacturer should be mounted in the pipe at regular intervals. These bearings are intended to prevent whipping of the shaft.

The motor must be kept dry. It should be placed where water will not drip into it. In warm humid weather there is always the tendency for moisture to condense on the cool tank and pipes. The pump house should be provided with drainage to prevent this condensation from collecting in pools or from finding its way back into the well.

The top surface of the pump foundation should be 4 to 6 inches higher than the surrounding floor and should slope about one-quarter inch to the foot away from the pump to insure drainage from it. The well casing should extend through the foundation 4 to 6 inches, or as high as the pump design will permit. ***It should be effectively sealed, so that no seepage from the foundation will find its way into the well.***

The hand pump may be bolted to the foundation, but a seal should be placed under it, as shown in figure 9. In the case of drilled and driven wells where the casing will support the pump it may be attached to the extended top of the casing, as shown in figure 5.

An ejector pump in a deep well will always be primed if it has a foot valve that does not leak, provided (1) the suction pipe extends more than 34 feet below the ejector, or is long enough to prevent the entry of air by the lowering of the water level below the end of the pipe, or (2) the ejector is placed below the lowest water level.

If the water level in the well drops below the foot valve, air will enter, and any appreciable air in the suction line will break the priming.

PRIMING

Most shallow-well and some deep-well pumps must at times be primed. Nothing is gained in exercising every precaution to protect the water supply from pollution or contamination if the water from a ditch, stock trough, or open rain barrel is used for priming. ***Use only safe water for priming the pump.***

The method of priming and the quantity of water required depends upon the design of the pump. The manufacturer gives complete instructions regarding the method, and experience will soon indicate the quantity.

FOOT VALVES

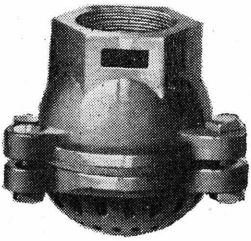


Figure 20.—Foot valve.

Centrifugal, turbine, ejector, and other pumps not normally provided with valves will lose their priming immediately unless a check valve is provided in the suction pipe. This is usually installed as a foot valve (fig. 20) at the lower end of the suction pipe and generally used in connection with a strainer. Foot valves are special forms of check valves, but as they are not usually so carefully made as check valves they will in time permit the water to leak back into the well.

If the use of a valveless pump is contemplated and the casing is too small to admit a foot valve, a check valve may be installed near the top of the well.

FROST PROTECTION

The small volume of water in an unprotected pump will freeze during cold wintry weather unless some means are provided to prevent it. A power pump should be housed in a frostproof structure. It is common practice in some localities to set it in a frostproof pit, but because of danger of polluting the well from pit drainage it is better to install it in an insulated pump house or in a well-drained basement.

Moisture is one of the electric motor's worst enemies. If a pump house is used, it should be provided with both ventilation and drainage. The pump house should be large enough for ample working space around the pump for making repairs. The roof should be equipped for removing pump rod, drop pipe, and well casing if the house is constructed over the well.

Protection against frost damage to hand and windmill pumps is usually made by providing a weep hole in the drop pipe above the cylinder and just far enough below the well cover to prevent freezing. The pipe to the tank must always be fully protected by insulation, since it is always filled with water.

POWER FOR PUMPING

Three types of power for pumping are practical—electric motors, windmills, and internal-combustion engines. The power required will vary somewhat with the type of pump, because on a given job some types are more efficient than others. The theoretical horsepower required may be determined by multiplying gallons per minute by total head in feet and dividing the product by 3,960 (33,000, the foot-pounds per horsepower, divided by 8.33, the weight of 1 gallon of water).

Since the theoretical power assumes 100-percent efficiency, it must be divided by an efficiency factor to obtain the actual power. The efficiencies of pumps vary considerably. If the efficiency is not known, an arbitrary value of 0.50 may be used for shallow-well and 0.30 for deep-well pumps.

The total head includes the total elevation from the surface level of water from which the pumping is done to the surface level to which it is pumped, or to the highest point to which it is forced by the pump, whichever is the higher. It includes also the pipe friction and back pressure of the pressure tank, both expressed in feet. Pressures expressed in pounds may be converted to feet by multiplying by 2.33 (the height of a column of water that will produce 1 pound pressure per square inch).

The following example will help to illustrate the method of determining power requirements:

Water is to be pumped to a pressure tank in the basement of the home by electric motor from a well in which the surface of the water is 85 feet below the pump head. The tank is 15 feet higher than the pump. Maximum pressure in the tank is 40 pounds. The distance from the well to the house is 170 feet, and 30 feet of pipe is required in the house to reach the pressure tank. Assume a 2½-inch drop pipe in the well and a 1¼-inch pipe from pump to tank. Assume also that a 480-gallon-per-hour pump (8 gallons per minute) is to be installed.

Friction head may be neglected for the 2½-inch drop pipe, but for the 200 feet of 1¼-inch pipe it will be 2×2.06 (the loss of head per 100 feet of 1¼-inch pipe), which is 4.12 feet (from pipe friction table).

Head due to pressure of tank is $40 \times 2.33 = 93.2$ feet.

Head due to difference in elevation is $85 + 15 = 100$.

Total head $= 4.12 + 93.2 + 100 = 197.3$ feet.

$$\text{Theoretical power required} = \frac{197.3 \times 8}{3{,}960} = 0.398.$$

Actual horsepower $= 0.398 \div 0.30 = 1.33$.

Use the next larger standard size electric motor, which is 1½ hp.

ELECTRIC POWER

Electric power is perhaps the most nearly universal and ideal of any of the available types of power for pumping. In the sizes below ¾ horsepower the general-purpose capacitor motor is recommended. It is especially adapted to loads requiring frequent starting and creates comparatively little radio interference. Repulsion-induction motors are recommended for pumps requiring motors of ¾ horsepower or larger.

The advantages of electric power are in its adaptability to automatic control and trouble-free operation. Electric motors are quiet and efficient. Most of them will start a load much greater than they are designed to carry continuously, hence they are ideally suitable for use with plunger pumps. They should be mounted on firm level surfaces where they will be free from dust and moisture and where they will get ventilation. Most shallow-well pumps are designed with platforms for mounting the motors.

Electric motors on pumps are usually started and stopped automatically by either a float switch or a pressure switch. If water is being pumped into an elevated tank a float switch should be used to start the motor when the water reaches a predetermined low level and to stop it when the tank is full. If water is pumped into a hydropneumatic tank a pressure switch will start and stop the motor at predetermined low and high pressures.

Pump motors should be equipped with overload and undervoltage control devices to prevent their burning out. The overload control

will stop the motor in case something should go wrong with the pump and place an overload on the motor. The undervoltage control will stop the motor if the voltage drops below a given value.

A motor mounted on the shallow-well pump or on the head of a deep-well pump is ordinarily effectively grounded by the pipe, which extends into the well. If rust or paint prevents the motor frame from making effective contact with the grounded pump, the rust or paint should be removed or a grounding connection installed. This can be done by placing one looped end of a No. 4 copper wire under the head of one of the studs that holds the end frame and the other looped end under a nut or bolt head on the pump or pump head, being sure that all paint and rust are removed to make a good contact.

WINDMILLS

Windmills have been used for many years as power for pumping water, grinding grain, and for other purposes where variations in speed are not important. The widespread adoption of electricity now provides a more dependable form of power, though windmills have a place as power units for pumping water in country where winds of 10 to 15 miles or more per hour can be expected over a large part of the year. The catalogs of most manufacturers give tables showing the quantities of water and the elevations to which they may be pumped with different wheel sizes and at various wind velocities.

In selecting a windmill determine first the water requirements and the height to which the water must be pumped; that is, the distance between the surface of the water in the well and the level to which it must be raised. Add pressure-head and pipe-friction losses. It is assumed that the well will produce all that is required; otherwise the outfit must be within the limits of its productive capacity. Select a windmill and pump that will meet these requirements. While no specific statement regarding wind velocity can be made, the following general rule may be followed: For use in the open Plains areas, select a mill that will do the job with wind at 15 miles per hour, and for use in hilly or mountainous country select one that will do it with wind at 10 miles per hour.

The number of strokes per minute for a windmill pump is governed by the design and size of the wheel. Consult the manufacturer's catalog to determine the length and number of strokes per minute, the size of cylinder for a given elevation, and the volume of water to be pumped. A long stroke is preferable with the larger wheels. The cylinder of a size sufficient to deliver the required quantity of water to the elevation desired with this length of stroke should be selected. The diameter of wheel required will be governed by the quantity of water, total head, and average wind velocity.

Some idea of the size of wheel may be obtained by determining the power required by calculation, just as was done for the electric motor, except that the windmill may operate 12 hours or more per day but at a lower efficiency than the electric outfit. Some idea of the power that may be expected from a windmill is given in table 2.

TABLE 2.— *Theoretical power of American multiblade windmills of different diameters for several wind velocities* [1]

Wind velocity (miles per hour)	Horsepower from wheel diameter (in feet) of—						
	6	8	10	12	14	16	18
6				0.05	0.06	0.08	0.09
8		0.05	0.07	.10	.14	.18	.23
10	0.05	.09	.14	.21	.28	.36	.46
12	.09	.15	.24	.36	.49	.63	.81
15	.18	.31	.48	.68	.94	1.21	1.55
20	.40	.72	1.12	1.62	2.20	2.88	3.65
25	.79	1.41	2.21	3.20	4.34	5.67	7.20

[1] Horsepower$=CD^2V^3$. Where C, the power coefficient for American multiblade type wheel$=0.45\times10^{-6}$, when the tip speed is approximately the same as the velocity of the wind; D=diameter of the wheel in feet; and V=indicated velocity of the wind in feet per second (Robinson anemometer). From Marks Mechanical Engineers' Handbook, third edition.

INTERNAL-COMBUSTION ENGINES

The internal-combustion engine is frequently used to furnish power for pumping. It may be made practically automatic in operation. A float or pressure switch may be used to open the ignition circuit and to stop the engine when the water in the tank or reservoir has reached the desired level.

By definition, 1 horsepower equals 33,000 foot-pounds per minute; that is, 1 pound raised 33,000 feet in 1 minute equals 1 horsepower. Any combination of feet multiplied by weight in pounds equaling 33,000 foot-pounds equals 1 horsepower, regardless of the type of power device used. As engines wear they lose efficiency; hence an engine of 25 to 30 percent higher power rating than that of an electric motor should be selected. Plunger-type pumps usually start under full load and thus place a short-time overload on the power device. The internal-combustion engine will stall if it is appreciably overloaded.

WATER STORAGE

Water storage may be either for a short or for a long time. The water may be obtained during the wet season and held for use during the dry season or it may be stored at night for use during peak demands. Cisterns are examples of long-time and pressure tanks of short-time storage. Water may be stored in wood, steel, concrete, or masonry tanks.

Storage tanks are frequently elevated to provide gravity delivery to all faucets. In hilly country they may be set in the ground on a hillside above the farmstead buildings, and in flat country they may be mounted on the windmill or other tower. The pressure at any faucet will be determined by the difference in elevation between its height and that of the surface of the water in the tank. When the water is flowing from the tank to the faucet, subtract the head loss caused by pipe friction. (See table 5, p. 46.)

ELEVATED TANKS

Tanks placed in attics, barn lofts, and on light trestles are usually unsatisfactory because of insecurity and leakage, lack of pressure, unwholesomeness in summer, and freezing in winter. Even though placing the tank in the attic or barn loft is not recommended, this location may be the only practical choice. Care must be exercised in reinforcing the joists and supporting columns to be sure that they will support the tank when full of water. If the tank is mounted on a tower, the supporting members must be substantial and well braced against the wind. The weight of the tank will depend upon the size and material. Water weighs approximately 8.3 pounds per gallon. A 500-gallon tank full of water weighs more than 2 tons. Provision for carrying the overflow to the outside of the building should be made.

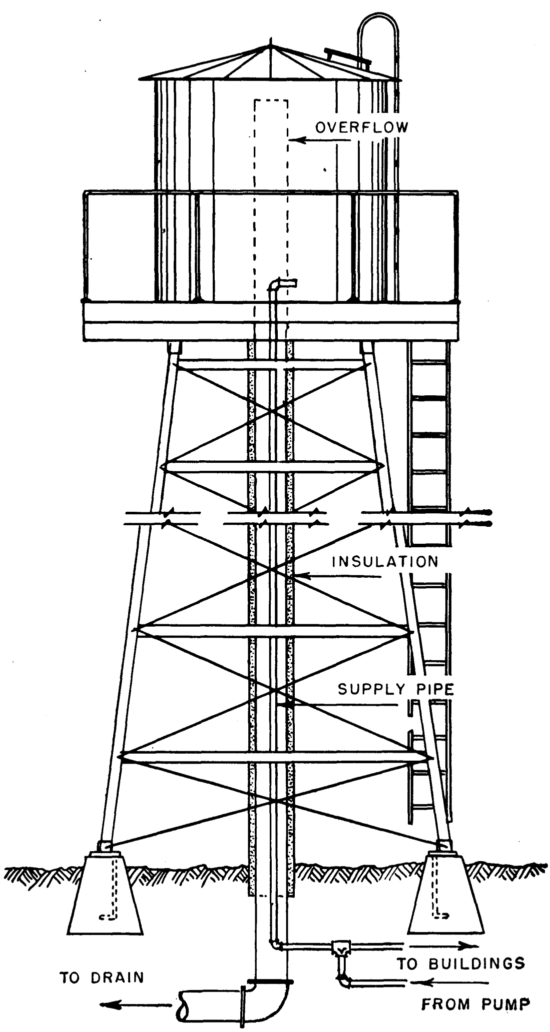


Figure 21.—**Elevated tank with overflow surrounding the supply pipe, insulation in place. Tank also may be insulated where long cold spells occur.**

Masonry tanks should be placed on a hillside or on a masonry tower. Where possible, an underground concrete tank placed on a hill is very desirable, as it escapes trouble from frost and provides a tempered water supply. Tanks for use with springs should hold more than 1 day's needs, preferably enough for 3 or 4 days, depending on yield of spring. An open tank for an automatic pumping-plant installation should hold about

1 day's supply. Where a windmill is used the requirements for a week or more may sometimes need to be stored. Tanks should be provided with waste pipes and valves to facilitate emptying and cleaning, and without fail should be covered tightly for protection against heat, cold, dust, vermin, and sunlight. Growths that impart an objectionable odor, taste, or appearance are likely to take place in ground and filtered waters that are exposed to the light. If water for fighting fire or for irrigation is to be stored, the tank should be large enough to supply peak demands.

An exposed storage tank such as would be placed on a tower should be insulated to prevent freezing. Suppose, for example, an elevated exposed cylindrical tank is 6 feet in diameter and 6 feet deep. Table 3 shows that this tank will hold 1,269 gallons. Suppose also the tank is kept full and the family and stock use half a tank of water per day. If the water is pumped into the tank at 50° F., approximately 45,000 heat units may be lost before the water will start to freeze. A tank of this size will have a surface area of approximately 170 square feet. At a temperature of 0° F., if we assume an average value of 41° F. in the tank, 0.27 heat unit may be lost per square foot each hour per degree difference in temperature without freezing. This is equivalent to the heat transmission of 1 inch of good dry insulation, such as mineral, rock, or glass wool.

TABLE 3.—*Capacity of circular tanks and cisterns*

Depth (in feet)	Capacity in gallons when diameter (in feet) is—								
	4	5	6	7	8	9	10	11	12
4	376	588	846	1, 152	1, 504	1, 904	2, 350	2, 844	3, 384
5	470	735	1, 058	1, 439	1, 880	2, 385	2, 938	3, 555	4, 230
6	564	881	1, 269	1, 727	2, 256	2, 855	3, 525	4, 265	5, 076
7	658	1, 028	1, 481	2, 015	2, 632	3, 331	4, 113	4, 976	5, 922
8	752	1, 175	1, 692	2, 303	3, 008	3, 807	4, 700	5, 687	6, 768
9	846	1, 322	1, 904	2, 591	3, 384	4, 283	5, 288	6, 398	7, 614
10	940	1, 469	2, 115	2, 879	3, 760	4, 759	5, 875	7, 109	8, 460
11	1, 034	1, 616	2, 327	3, 167	4, 123	5, 235	6, 463	7, 820	9, 306
12	1, 128	1, 763	2, 537	3, 455	4, 512	5, 711	7, 050	8, 531	10, 152

A further reduction of heat loss will be experienced if the outside of the tank is coated with white or aluminum paint. The insulation and paint will retard the entrance of heat during hot weather, thus assuring cooler water than would be obtained from an uninsulated, unpainted tank.

Provision must be made for keeping the insulation dry all the way from the top of the tank and down the overflow pipe in the ground. The overflow pipe should open several inches below the top of the tank. It is convenient to place the supply pipe inside the overflow pipe (fig. 21), for the air space between them will help protect the supply pipe from freezing.

Wooden and steel tanks are usually built cylindrical, but tanks constructed of concrete may be made any shape necessary to conform with space or other structural design. Circular tanks are more

economical of materials. The capacity of circular tanks or cisterns is shown in table 3. The dimensions are inside measurements.

HYDROPNEUMATIC TANKS

Water can be stored and delivered to the faucet by the use of a hydropneumatic (water-air) tank. The tank need not be elevated and usually is conveniently located in a utility room, basement, or pump house. Hydropneumatic tanks must be absolutely air-tight. Air being lighter than water occupies the upper part of the tank, and it presses with increasing force against the water as either more water or more air is pumped in.

Under pressure, the water gradually absorbs the air, and this absorption is the more rapid the higher the pressure. From time to time, therefore, the air supply must be replenished, or the tank becomes waterlogged. Maintenance of the air supply is a vital factor. Outlet pipes must enter at the bottom of the tank. Hydropneumatic tanks are made of 3/16-inch or thicker steel with riveted and calked or welded joints. A range boiler or other thin-walled tank should not be used for this purpose. The smaller tanks are usually galvanized and may be set vertically or horizontally; the large tanks are set horizontally. A typical installation is shown in figure 17.

To obtain the best service from a hydropneumatic tank it is necessary to carry an initial or excess air pressure. that is, enough air to give pressure when no water is in the tank. The proportion of water to the total capacity of any tank, set either vertically or horizontally, under varying conditions of gage pressure and initial air pressure, is shown in table 4. This shows that if water is pumped into a tank having no pressure above that of the atmosphere until the gage shows 5 pounds the tank will be one-fourth (0.25) filled with water; at 15 pounds it will be about half (0.51) full; at 30 pounds it will be two-thirds (0.67) full; at 45 pounds it will be three-fourths (0.75) full; at 60 pounds it will be four-fifths (0.80) full.

As an example, suppose a 220-gallon tank is half full of water under a gage pressure of 45 pounds and it is desired to know what quantity can be drawn before the pressure reaches 25 pounds. Reference to table 4 shows that if the tank is half (0.50) full at 45 pounds the initial air pressure must be 15 pounds, and under that initial pressure the tank is one-fourth (0.25) full at 25-pounds' gage pressure. Therefore, 0.50 minus 0.25 equals 0.25, which, multiplied by 220 (capacity of tank), equals 55 gallons, the available quantity. In general, the working capacity of a tank is about 25 percent of its total capacity, but it can be increased by increasing the proportion of air.

It is usually more economical to purchase a pump with sufficient capacity to carry the peak requirements than to purchase a pressure tank large enough to carry a sustained heavy demand. Water from the smaller tank will be fresh. No fixed rule has been established, but experience suggests that a 42-gallon tank is practical for the average home.[5]

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[5] Recommendation of the Associated Water System and Allied Product Manufacturers, in Standard Manual on Selection, Installation, and Operation of Water Supply Systems.

TABLE 4.—*Proportion of water to the total capacity of any hydropneumatic tank (based on atmospheric pressure of 14.7 pounds per square inch) at different gage pressures*

Gage pressure (pounds)	Proportion of water to total capacity when initial air pressure (in pounds) is—					
	0	5	10	15	20	25
5	0. 25					
10	. 40	0. 20				
15	. 51	. 34	0. 17			
20	. 58	. 43	. 29	0. 14		
25	. 63	. 50	. 38	. 25	0. 13	
30	. 67	. 56	. 45	. 34	. 22	0. 11
35	. 70	. 60	. 50	. 40	. 30	. 20
40	. 73	. 64	. 55	. 46	. 37	. 27
45	. 75	. 67	. 59	. 50	. 42	. 34
50	. 77	. 70	. 62	. 54	. 46	. 39
55	. 79	. 72	. 65	. 57	. 50	. 43
60	. 80	. 74	. 67	. 60	. 54	. 47
65	. 82	. 75	. 69	. 63	. 56	. 50
70	. 83	. 77	. 71	. 65	. 59	. 53
75	. 84	. 78	. 72	. 67	. 61	. 56
80	. 85	. 79	. 74	. 69	. 63	. 58

Water should be delivered directly from the pump to the pressure tank and should be withdrawn from the bottom of the tank. It is occasionally convenient to tap the pump-delivery pipe for a faucet before the water reaches the pressure tank. Such connections should be made on the lower side of the delivery pipe, so as not to remove the air on its way from pump to pressure tank.

CISTERNS

Although cisterns may be used to store water from wells or from other sources, they are usually used to store rain water collected from the roofs of buildings. Rain water is soft and, when properly handled, is comparatively pure. Its advantages for washing and laundering are well known.

Certain features of cistern design and construction are vital to the collection and storage of drinking water. Some of these features are: (1) Watertightness, (2) close screening of inlet and overflow, (3) provision for diverting from the cistern the first part of each rainfall until the collecting area has been thoroughly washed, (4) an effective filtering system, (5) an overflow pipe to remove water from the bottom of the cistern, and (6) capacity sufficient to carry over protracted dry spells. A well-designed cistern is shown in figure 22.

Most of the objectionable features of cisterns and cistern water can be overcome by careful management. Although the rainfall cannot be controlled, wasteful use of cistern water can be avoided. Freezing may cause some trouble in the supply. The entrance of dust, soot, bird droppings, and other pollution from the roof may

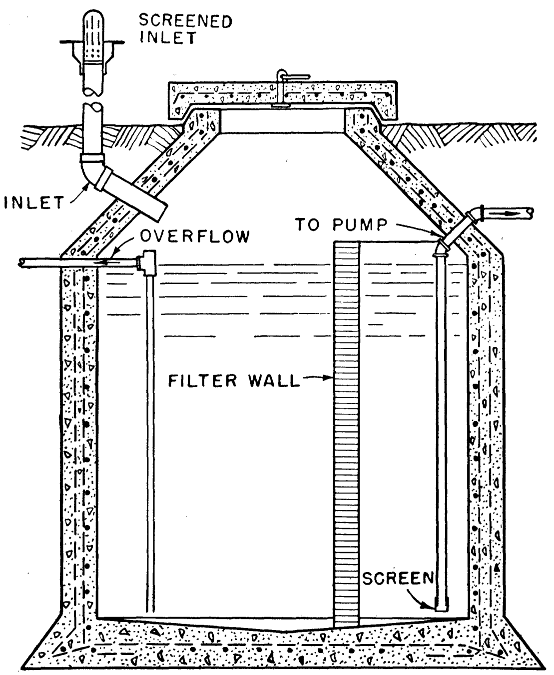

Figure 22.—**Cisterns filled by water that enters directly from the downspout. If a sand-charcoal filter is used in conjunction with the cistern the downspout should empty into this filter. The cistern here illustrated has a curved filter wall built in, the space inside being large enough to allow a man to enter for cleaning or making repairs.**

be largely prevented by diverting the first runoff waters away from the cistern. This can be done by arranging the downspouting to keep all rainfall from the cistern until the roof is washed clean. The quantity of waste will depend upon the intensity of the rainfall and the kind of contaminating material that accumulates between rains.

Green growth does not develop if light is excluded. In new cisterns the lime taste can be largely eliminated from the water if before use the concrete is allowed to cure thoroughly (4 to 5 weeks). The walls can be washed with a strong solution of ordinary baking soda and rinsed with clean water. Filling the cistern and pumping it dry once or twice will then practically eliminate the lime taste.

A properly constructed cistern should exclude all animals, birds, reptiles, tree roots, and foul seepage. Even in well-managed cisterns, however, some undesirable material will collect. Much can be done to avoid the entrance of debris by passing all inlet water through a filter. The cistern should be pumped dry and thoroughly cleaned at least once each year.

Cisterns may be constructed in any shape desired. Round cisterns are more economical of material but may be somewhat more difficult to build. Concrete walls should be 8 inches thick. Brick cisterns are usually circular with 8-inch walls. The joints should be completely filled and the inside surface should be heavily plastered with rich cement-and-sand mortar.

To determine the quantity of water falling on a roof, measure horizontally in feet the ground plan of the roof and compute this area in square feet; multiply this by the rainfall in inches (for the wet-weather period, which must supply the desired storage); and multiply the product by 0.625 (or $144 \div 231$, where 144=number of

square inches per square foot; 231=number of cubic inches per gallon). The result is the approximate fall in gallons.

The householder who would avoid the inconveniences of a shortage in his cistern supply is fully warranted in planning a large installation. Most localities experience long droughts or exceptionally dry years when the rainfall totals only one-half or one-third of normal. Moreover, it may be impracticable to collect many small rains because of the dirty condition of the roof. At least one-third of the estimated rainfall should be deducted to take care of leakage, water required to wash the roofs, and evaporation. On the other hand, it is not economical to build a larger cistern than can be filled by the average rainfall.

To find the capacity of square or rectangular cisterns and tanks, multiply the inside length by the breadth and the product by the height, each dimension being in feet. Multiply the result (cubic feet) by 7½ to find the gallons. The capacity of round cisterns of certain dimensions is shown in table 3.

If a good well is available and a cistern is contemplated merely to take care of the soft-water requirements, thought should be given to the cost of providing two pressure systems. It may be more economical and satisfactory to filter the well water through a zeolite softener, which can be installed in the pressure system.

PONDS

In certain parts of the country ground water is either not available or if found is entirely unsatisfactory. In such cases surface runoff may be impounded and used for domestic purposes. A great deal of care is required in handling such sources of water. The watershed draining into the pond must be kept as free of pollution as possible. Ponds used as sources of water for domestic purposes should be fenced to prevent stock from entering. Fish will help to control mosquitoes. The banks should be steep and kept free of vegetation that might harbor vermin.

Where natural ground water is difficult to obtain, as in parts of the West, seepage from irrigation ditches is sometimes used. This seepage can be collected in drain tiles laid crosswise of the direction of water movement, usually parallel to the shore line. It is advisable to locate the collector tile 50 feet or more from the surface supply and below the low-water levels of the ponds or ditches. Where feasible, the ground water should not be allowed to reach the surface soil. Collectors may be of tile, wood, stone, or brick, and there should be ample openings, particularly at the bottom, for water to enter. If the seepage is slow the interceptors may be lengthened to increase the yield (rate of collection). Sand and charcoal filters are sometimes used, but they do not remove disease germs and bacteria. Chlorine treatment of all surface water to be used for domestic purposes is recommended. For a fuller discussion of farm ponds see Farmers' Bulletin 1859.[6]

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[6] HAMILTON, C. L., and JEPSON, H. G. STOCK-WATER DEVELOPMENTS: WELLS, SPRINGS, AND PONDS. U. S. Dept. Agr. Farmers' Bul. 1859, 70 pp., illus. 1940.

PIPES AND PIPE FITTINGS

Galvanized wrought-iron or steel pipes with threaded fittings are most generally used. Copper and brass tubings are used to some extent, but are not suitable for all waters. The size depends upon the quantity of water handled. Standard weight is satisfactory for ordinary working pressures. Extra-strong pipes must be used for high-pressure spray or fire-fighting equipment. For information on farmstead plumbing see Farmers' Bulletin 1426.[7]

TABLE 5.—*Friction loss in feet per 100 feet of 15-year-old iron pipe* [1]

Discharge in gallons per minute	Friction loss (in feet) for pipes of diameters (in inches) of—								
	½	¾	1	1¼	1½	2	2½	3	4
1	2.1								
2	7.4	1.9							
3	15.8	4.1	1.26						
4		7.0	2.14	0.57	0.26				
5		10.5	3.25	.84	.40				
6		14.7	4.55	1.20	.56	0.20			
8			7.8	2.03	.95	.33	0.11		
10			11.7	3.05	1.43	.50	.17		
16				7.3	3.41	1.20	.41		
20				11.1	5.2	1.82	.61	0.25	
25				16.6	7.8	2.73	.92	.38	0.09
30					11.0	3.84	1.29	.54	.13
40					18.8	6.6	2.20	.91	.22
50						9.9	3.32	1.38	.34
100							12.0	4.96	1.22

[1] This table is based on Hydraulic Tables, Williams and Hazen, 1909. Coefficient here used is 100, a fair value where the interior of iron pipes is roughened by 10 to 15 years' pitting and rust accumulation.

The inner surface of a pipe is never perfectly smooth, and it gets rougher as it becomes pitted or incrusted with age. Water flowing next to a rough pipe wall becomes turbulent. The higher the velocity the greater the turbulence. As the turbulence increases, more energy is required to drive a given quantity of water through the pipe. The energy consumed in overcoming turbulence serves no useful purpose from the pumping standpoint and is known as friction loss, or friction head. Pipes installed should be large enough to hold friction losses to a minimum. The estimated cost of equipment and operation with one size of pipe should be balanced against the cost of larger and smaller sizes to determine the proper size to install. The loss in feet because of friction in 100 feet of 15-year-old iron pipe is shown in table 5.

[7] WARREN, G. W. FARM PLUMBING. U. S. Dept. Agr. Farmers' Bul., 1426, 21 pp., illus. 1924 (rev. 1946).

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